UNIVERSITY FOR DEVELOPMENT STUDIES, TAMALE

LONGITUDINAL ANALYSIS OF WEIGHTS OF BABIES IN BOLGATANGA MUNICIPALITY

BY

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DECLARATION

Student

I hereby declare that this thesis is the result of my original work and that no part of it has been presented for another degree in this university or elsewhere. Related works by others which served as a source of knowledge has been duly referenced and acknowledged.

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ABSTRACT

Weights and ages of babies play vital role in the administering of a particular quantity of drugs which could either constitute overweight or underweight. Research works have been done using various techniques to model weights of babies and to find out causes of low birth weights as well as high birth weights per World Health Organization standards(i.e. normal birth weight of a baby = 2.5kg) of children in Ghana and Africa as a whole but little work is done on the issue of developing a model to predict the weights of infants as well as determining the biological and maternal demographic factors influencing the weights of infants as well as adults. This research work is geared towards determining the pattern in change of weights of babies as well as any pattern differential among some of the groups, identify the factors that significantly affect the change in weights of babies and to develop Gompertz and Mixed models for prediction of weights of babies in the municipality. The dependent variable is the weights of babies whilst the independent variables are gender, breast feeding type, marital status, age of mother, parity, type of health facility, mother's religious denomination, educational status of mother, occupation of mother and last type of family planning mother ended with before becoming pregnant. Maternal factors such as family planning type, parity group and religion significantly determined birth weight whilst biological determinants such as gender, breast feeding type as well as maternal factors which included marital status, age of mother, and mother's educational and occupational status variables in the equation were statistically not significant. Following the analysis using Stata, it is found out that there is significant difference in mean weights of babies among the maternal factors. The models that fit the data for this research work are the Gompertz and the reduced models.

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DEDICATION

This work is dedicated to Madam Juliana my mum, my sister Sakinatu and her children, my wife Judith, my lovely children Silas and Dymphyna and the entire Akansuke family.

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ACRONYMS

AFMC	Afrikids Medical Centre
AH	Amiah Hospital
AHC	Asankunde Health Centre
ANOVA	Analysis of variance
AZHC	Aningazanga Health Centre
BFHS	Botswana Family Health Survey
CC	Coronation Clinic (Plaza)
CHPS	Community-based Health Planning Services
DMHIS	District-wide Mutual Health Insurance Schemes
GDHS	Ghana Demographic Health Survey
IUGR	Intra-uterine Growth Restriction
IUGR	Intrauterine Growth Retardation
JHS	Junior High School
LBW	Low Birth Weight
MANOVA	Multivariate analysis of variance
MDG	Millennium Development Goal
MICS	Multiple Indicator Cluster Survey
ML	Maximum Likelihood
NHIS	National Health Insurance Scheme
REML	Restricted Maximum Likelihood
RH	Regional Hospital
SGA	Small for Gestation Age

SHS	Senior High School
UK	United Kingdom
UNICEF	The United Nations Children's Fund
US	United States
WHO	World Health Organization
ZHC	Zuarungu Health Centre

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Studying the growth pattern of natural and social phenomena has become increasingly important to researchers because it provides means for visualizing growth patterns over time, and the equations gotten help in making reasonable predictions of expected growth rate of these phenomena at a specific instant of time thus indicating permanent increase in the size of any object of interest to researchers (Tzeng & Becker, 1981; Yakupoglu & Atil, 2001; Sengul & Kiraz, 2005).

Nonlinear regression is an extended linear regression technique in which a nonlinear mathematical model is used to describe the relationship between the response variable and the predictor variables (Bales and Watts 1988). A nonlinear regression model is a model that contains at least one of the parameters in a nonlinear form.

Growth which is a permanent increase in size over time was modeled as an exponential function. The earlier of such models were the Malthusian exponential population models (Malthus, 1798). Exponential models had limitations due to the fact that things which are capable of growing do so within certain bound but the Malthusian models give an impression that growth is boundless which is perfectly true in mathematical or theoretical sense but deviates from growth of organisms. To overcome the limitations of the exponential models, logistic model is proposed (Chasnov, 2009) which included the restriction required to make accurate prediction of growth has been studied and used to model growth in several fields of study such as agriculture, biology, economics, physics, finance and chemistry. Pearl and Reed (1920) modeled growth with logistic curve.

The Gompertz growth curve has also been studied and used extensively in phenomena in the actuarial science. Comparing the characteristics of logistic and Gompertz growth models was presented in a paper by Winsor (Winsor, 1932) and he concluded that neither in reality seemed superior in terms of accuracy in prediction of growth at a certain point in time.

Wright (1926) first used the Gompertz curve in modeling biological growth. Also, Wright and Davidson (1928) carried out studies where they used the Gompertz curve to illustrate the growth in body weight of cattle. The growth and development of children between 1997 and 2003 the world over was assessed using growth curves which was in response to World Health Organization under the Multicentre Growth Reference Study (MGRS).They combined a longitudinal follow-up from the time of birth to age 24 months as well as a cross-sectional survey of children between the age bracket of 18 to 71 months. A total of 8440 primary growth data and related information were gathered for the analysis. The survey was basically designed to come out with a standard by choosing healthy children from mothers who used health-promoting practices living under conditions likely to favor the achievement of their full genetic growth potential (WHO, 2006).

In Ghana, a child born either at home or in a health facility is mandated to have a postnatal care (care given to the mother and the child one month after birth) and subsequent monthly weighing of the baby known as child welfare care. The reasons for the child welfare care include: growth monitoring of the child, for early detection of any abnormal growth existing condition for referral to the appropriate health unit for special attention, for immunization against the six childhood killer diseases and for counselling of the mothers with regards to the welfare of both the child and the nursing mother.

The first month of life, called the newborn or neonatal period is the riskiest period in the life of every individual because whilst inside their mothers, babies are safe, warm and well fed.

After birth, newborns have to adapt to a different way of feeding, breathing and staying warm otherwise they can get sick easily leading to death. Thus, the health and survival of newborn children depend largely on their weights and how they are cared for. Out of every 100 children born alive, about 10 die before reaching the age of five years (WHO, 2012).

Statistics of Ghana Demographic Health Survey (GDHS,2005) and Multiple Indicator Cluster Survey (MICS, 2006) suggest that child mortality is increasing with a shocking drop in performance by the Upper East Region even though the country tries hard to reduce under-five Mortality Rate of the Millennium Development Goals 4 and 5 by 2015.

A five year child survival program known as Essential Newborn Care started in 2012 with Bolgatanga Municipality as well as the other municipalities and districts within the region is designed to improve the birth, soon after birth and the postnatal period (UNICEF, 2013).

The health and survival of newborn children depend largely on how they are cared for. Recent worldwide evaluation points to the fact that commitment to raising the standards of the health status of newborn babies' yield meaningful socio-economic contributions (Yinger and Ransom, 2003).

Further research on newborn babies revealed that child survival programme has assisted in the reduction of death rates among under-five year old babies over the past twenty five 25 years and the greatest impact has been on reducing mortality from diseases which attack infants and children over one month old. Hence, huge proportions of infant mortality take place between the first month of life (the neonatal period), a period when a child's risk of death is almost fifteen (15) times greater than at any other time before the first birthday (Yinger and Ransom, 2003).

Tinker and Ransom (2003) stipulated that, though newborn health is closely related to that of their mothers, newborns have a unique need that must be addressed in the content of maternal and child health services. Their further argument was that millions of newborn deaths could be avoided if more resources were invested in proven low-cost interventions designed to address newborn needs.

A similar research on newborn babies estimated that almost two-thirds of infant mortality occurs in the first month of life, of which more than two-thirds die in their first week, and among them, two-thirds die in their first 24 hours (Lawn, 2001).

The World Health Organization define low birth weight as weight at birth less than 2.5 kg. The global prevalence of low birth weight is 15.5%, which means that about 20.6 million of such infants are born each year with 96.5% of them in developing countries.

There is significant variation in low birth weight rates across the United Nations regions with the highest in south-central Asia (27.1%) and the lowest in Europe (6.4%).

There are two types of low birth weight infants, that is, small-for-date and pre-term babies. Small-for-date infants are those who are delivered after a full gestation period of 37-40 weeks but due to intrauterine growth retardation (IUGR), their birth weights are below 2.5kg.

Furthermore, low birth weight can be caused by short gestation duration, (less than 37 weeks) as in the case of pre-term babies.

Low birth weight is immensely connected with fetal and neonatal morbidity and mortality (McCormick, 1985; Gortmaker & Wise, 1997; Caulfield *et al.,* 2004). It is also a potential recipe for impaired cognitive development and the advent of chronic diseases in later life including diabetes and coronary heart disease (Bale *et al.,* 2003).

It is believed that the better a population socio-economic development, the better its health indicators. The proportion of infants with low birth weight reflects the socio-economic development of any region or country (Murthy, 1991).

This is based on epidemiological observations that infants weighing less than 2,500g are approximately 20 times more likely to die than heavier infants (UNICEF-WHO, 2004).

Low birth weight is mostly common in developing countries, where the burden of malnutrition and infectious diseases is heavy, and the incidence is estimated to be more than twice that of developed countries (Dryfuss *et al.,* 2001). Being born with low birth weight is generally recognized as a disadvantage for the infants and such infants are at higher risk of early growth retardation, infectious disease, development delay and death during infancy and childhood.

In sub-Saharan Africa, estimated rate of low birth weight is 14% live birth based on statistics derived from health facilities, which constitute about 35% of all live births occurring in the region. Similarly, based on health facility statistics of 1999, which included only 45% of infants weighed at birth, indicated incidence rate of low birth weights in Tanzania was13% live births (UNICEF-WHO, 2004).

In a literature survey, de Onis *et al.*, (1998) found that IUGR infants are at increased risk of prenatal mortality and morbidity; that is they are prone to sudden infant death syndrome. Furthermore, they are likely to suffer poor cognitive development and neurologic impairment, cardiovascular disease, high blood pressure, obstructive lung disease, diabetes, high cholesterol concentrations and renal damage in adulthood. Such children remain a burden on government expense in developed countries and a permanent problem for their families in developing countries.

The incidence of LBW irrespective of gestational age is estimated to be 16 per 100 worldwide, 19 per 100 in the least developed and developing countries and 7 per 100 in the developed countries. The issue of LBW is 31 per 100 in south Asia followed by Middle East and North Africa with 15 per 100, Sub-Saharan Africa with 14 per 100, East Asia and Pacific 7 per 100. Asia accounts for 75 per 100, out of the total estimated IUGR infants with short gestation duration (less than 2,500g and greater than or equal to 37 weeks) and with 20% and 5% born in Africa and Latin America, respectively.

1.2 Problem Statement

In Ghana, much needed attention has not being given to the issue of birth weight and the factors that influence it. Since birth weight is a strong predictor of a baby's survival and personality, it has to be an issue of public health concern for any country. According to UNICEF and WHO in 2004, from 1998 to 2004 Ghana recorded higher low birth weight cases of 16% compared to the average of 14% in the Sub-Saharan Africa. The Multiple Indicator Cluster Survey (MICS,2006) report however found that the prevalence rate of low birth weight to be 9.1% with the difficulty being that 2 in 5 babies were only weighed at birth. Even though gestational age is the major and primary determinant of birth weight, there are other secondary factors which either directly or indirectly affect the determination of a baby's weight at birth.

The Low Birth Weight situation in Ghana is a very serious Public Health problem among pre-school children and the factors influencing it in Ghana has not received the needed attention. This does not differ from the problem in developing nations. Evidence

The diversity in area-status (ethnicity) and differential in overall geo-demographic factors suggest a need to investigate low birth weight and mean birth weight in a given geographical area.

UNICEF-WHO, 2004 shows that in Ghana, the rate of low birth weight infants is 9 per 100.

1.3 Research questions

The study objectives of this research work will be achieved if and only if the questions below are properly addressed:

i. What is the nature of the growth of the weights of babies?

ii. Are there pattern differentials among some of the maternal groups?

iii. Which maternal factors significantly influence the mean change in weights of babies?

iv. Which model is more appropriate for predicting the weights of babies?

1.4 Objectives of the study

1.4.1 General Objective

To analyse longitudinal data of weights of babies in Bolgatanga Municipality of the Upper East Region of Ghana.

1.4.2 Specific Objectives

The specific objectives are to:

- determine the nature of growth of weights of babies
- determine any pattern differentials among some of the groups such as gender, breast feeding type, marital status, maternal age group etc.
- identify the maternal factors that significantly affect the change of weights of babies.
- Compare the Gompertz and the logistic growth models for predictions of weights of babies.

1.5 Limitations of the study

This study analyzed only the weights of babies which were obtained from Bolgatanga Municipality from January 2013 to December 2013 using seven major health facilities. Weights of babies at birth up to.

1.6 Significance of the study

The fourth goal of the Millennium Development Goals have Goal four which aims at ensuring a reduction in child mortality by two-thirds between the years 1990 and 2015. However, with barely a few months to 2015, a lot of African nations are far from meeting this target. This stems from the fact that not much is being done in this regard. For instance, Sokol et al., (2007) stated that poor feeding practices suggest sub-optimal breastfeeding is still widespread and often leads to malnutrition which is a major cause of more than half of all child deaths. What is more, birth weight is a significant predictor of infant survival within the first year of life. It is also linked to child development and later adult onset of morbidity.

For instance, low birth weight has been dubbed as the most powerful indicator of infant survival and strongly associated with mortality. Worthy of observation is the 2008 Ghana Demographic and Health Survey (GDHS) which was on the fifth Demographic and Health Survey conducted in Ghana and was designed to measure levels, patterns, and trends in demographic health indicators. It indicated that the rate of anemia in children of the Upper East was 89%.The report indicates that the results in stunted growth of children in the region which is mostly attributed to the birth and subsequent weights of the babies in the Municipality. The results observed that the incidence is assuming an alarming proportion, which poses serious threats to the quality of health care in the region and the country at large.

Every effort to deal with the menace of infant mortality associated with birth weights must begin with a serious effort to understand its dynamics. It is therefore obvious that one needs to comprehend the pattern of the birth and subsequent weights of babies in the

Municipality, together with the relevant demographic factors of the mothers of those babies and the effects these factors have on the weights of the babies.

This study aims at identifying and bringing to light the growth trajectory and mean weights of babies in the municipality as well as maternal factors that significantly influence the birth and subsequent weights of babies. This work will not only indicate the kind of birth weights (i.e normal birth weight of 2.5kg, under weight of below 2.5kg and overweight of above 2.5kg) including the pattern of mean change in weights in the study area overtime but also contribute significantly to a better understanding of the essential health interventions. It has also showed that the Gompertz model could be more appropriate for the prediction of weights of babies in the municipality.

It is hoped that the results of this research work will contribute tremendously to the growing body of scientific knowledge on maternal factors as well as biological factors of the baby that significantly impact on birth and subsequent weights of infants in Ghana. This will inform the stakeholders and policy makers to design and situate appropriate health interventions in the Ghanaian community.

1.7 Organization of the Thesis

The study is divided into five (5) chapters, Chapter one constitutes the background of the study, problem statement, objectives, limitations, significance, of the study and organization of the study. Chapter two reviews literature that is relevance to the study which is followed by chapter three which presents the methodology, which is concerned with the methods of data collection and the appropriate statistical tools used for the data analysis. Chapter four comprises detailed analysis and presentation of the data. Finally, the main findings of the research, as well as recommendations are contained in Chapter five to conclude the study.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This chapter provides a modest review of relevant and related literature on important studies in the area of child health. The discussions will centre on the following headings: Socio-demographic risk factors of the mother, maternal behavioral risk factors and biological factors of the baby.

About 70% of low birth weight is as a result of babies born before 37 weeks (pre-term) and there are numerous risk factors for pre-term births, which include; carrying more than one baby, a history of pre-term births, exposure to tobacco smoke, environmental stressors, bladder or vaginal infections during pregnancy, or previous abortions (Kieley et al.,1994).

2.1 Socio-demographic risk factors

In the context of developing countries where institutional delivery is very low, concentrating only on the children weighed at a health facility creates some information gap. The effects of socio-economic, biological and nutritional attributes of low birth weights are well documented (Klufio et al, 2000; Dreyfuss et al, 2001).

Attention has to be paid to socio-demographic factors such as age, marital status, parity, ethnicity, occupation, sex of the baby, religion, breast feeding type during first six months of birth and type of family planning practiced before conception.

2.1.1 Maternal Age

Several studies have identified age of mothers to be one of the key factors that relate directly to birth (Deshmukh et al., 1998; Stephenson and Symons, 2002; UNICEF, 2003; Torres-Arreola et al., 2005; Negi, et al, 2006; Khatun & Rahman, 2008).

Utilization of maternal health services such as immunization against tetanus is further assumed to be complementary to other inputs that improve the health of the womb, such as presumptive malaria treatment and avoidance of risk behaviors (Dow et al., 1999).

Maternal age constitutes an important risk factor. Foix-L and Blondel (2000) found that in France maternal age above 34 years old constituted an important risk factor in both a 1981 and a1995 study. Maternal age below 20 years also constituted an important risk factor in 1981 but not in 1995 study.

Similar results were obtained by Dickute et al., (2004), who in their study of Lithuania in 2001-2002 identified a U-shaped relationship between maternal age and low birth weight risk (younger than 20 years and 35 years and older, although other factors also clearly played a role.

Foix-L'Helias and Blondel (2000) and others have demonstrated that a higher maternal age (e.g. above 34 years old) remains an important risk factor. Other authors have also found a strong relation of a higher maternal age and the risk for premature birth. Astolfi and Zonta (2002) found that the 35 plus age group always has a significantly higher risk of still or preterm birth, or low birth weight at term, even when parity and education variables are controlled.

A French study has similarly found negative consequences of delayed childbearing (35 plus) in the format of higher fetal death rates (Breat, 1997).

Similar findings were also reported by Tough et al. (2002) in a study conducted in Alberta, Canada, which concluded that only those age 35 and older of first parity contributed to the population increase in LBW. The negative effect of a higher maternal age can be made weak by education and parity, but only to a rather small extend Astolfi and Zonta (2002), referring also to the Danish case study of Basso et al,(1997).

Earlier research works (Friesen et al.,2001) indicated that teenage mothers are associated with a short cervix and a small uterine volume which is associated with preterm birth and consequently low birth weight (Gibbs et al.,2012) .Additionally, glycine, an important amino acid necessary for many metabolic processes in the body including the proper growth of a fetus, may be compromised in young mothers and poor placenta glycerin transfer has been identified as a contributing factor in preterm and low birth weight offspring (Friesen et al.,2001).

2.1.2 Maternal Educational Status

A lot of studies conclude that higher levels of maternal educational attainment lead to better pregnancy outcomes. Raum *et al.,* (2001) examined the influence of maternal education on IUGR in two different political and social systems, West and East Germany in 1987/88 and1990/91 respectively. They found out that mothers lowly educated in both West and East Germany had an unadjusted relative risk of 2.5 for delivery and Small for Gestation Age (SGA) child compared to the highly educated.

In another research, (Sachdeva et al., 2013) when a mother is able to finish high school she has an increased chance for more favorable outcome in pregnancy. Additionally, a rising level of education is a protective factor against low birth weight. The lower the educational level, the greater the vulnerability of delivering a baby with a low birth weight (Silvestrin et al., 2013).

2.1.3 Marital Status

Foix-L'Helias and Blondel (2000) indicated that the 1995 study of the association between marital status and preterm birth of countries such as Finland, Sweden and France did not show any association between marital status and preterm birth.

Similar research works showed that the risk of low birth weight among older mothers could possibly be related to several factors such as cardiovascular disease, hypertension, diabetes and other diseases that can be associated with older age (Nazari et al., 2013).

2.1.4 Maternal Occupation

Poverty is usually the culprit and the physical demands on these mothers to earn wages can contribute to poor fetal growth (UNICEF and WHO, 2004).These mothers typically do not receive the proper nutritional care or health to in turn deliver a healthy offspring.

2.1.5 Maternal religion

The link between religion and birth weights has not been clearly established since evidence provided by different studies has produced conflicting results. Ward (1987) reported in a study that religion did not influence birth weight but Dhall and Bagga (1995) used multiple regression model to reveal a significant effect of maternal age, parity, height, weight and religion on birth weight among babies born in North India.

2.1.6 Gender of baby

Onwuanaku et al., (2011) worked on the effects of birth weight and gender on neonatal mortality in north central Nigeria and concluded that birth weight unlike gender is a significant predictor of mortality.

2.1.7 Breastfeeding type

Previous research by Stuarted-Macadam et al. (1995) proved that breastfeeding has been reported as an age-old practice that has been very critical not only to the physiology, growth, and overall well-being of neonates but also the physiology and health of women.

2.2 Behavioral risk factors

Numerous studies have explored psychosocial, physical and economic consequences of overweight and obesity (Paul, 2005).Childhood overweight affects self-esteem and as negative consequences on cognitive and social development (Hesketh et al., 2004; Tremblay et al., 2000).

Childhood obesity places children at risk for a host of health conditions including hypertension, impaired glucose tolerance, type 2 diabetes mellitus, chronic inflammation, sleep apnea, and orthopedic complications (Hughes & Reilly, 2008; Thompson et al., 2007).

Another research indicated that conditions such as type 2 diabetes mellitus, hypertension, and hypercholesterolemia, which were previously seen primarily in adults, are becoming more common among children as the prevalence of obesity increases (Must and Strauss, 1999).

Epidemiological research also suggests that childhood obesity endures into adulthood, making early health risks a chronic reality (Freedman, et al., 2009; Lagstrom et al., 2008; Rao, 2006; Schmitz and Jeffrey, 2002).

Due to increasing childhood obesity a rising number of adults will be at increased risk of cardiovascular diseases, osteoarthritis, and types of cancer (Dietz, 2004; Manson and Bassuk, 2003). As a result, the obesity epidemic would cause a substantial decrease in the quality of life and life expectancy and accounts for billions of dollars in health care spending (Fortaine, et al., 2003; Katzmarzyk & Janssen,2004).

Given the severity and causes of obesity throughout the lifespan, it is not surprising that in New Delhi, Indian the national health care costs related to the disease approach US$100 per year (Rao, 2006).

2.3 Other risk factors

Guyatt and Snow (2004) also argued that malaria infection has a substantial adverse effect on pregnancy outcomes causing both premature birth (gestation of less than 37 weeks) and intrauterine growth retardation, which lead to low birth weight.

Employing the 2006 Uganda Demographic and Health Survey (UDHS) data, 2006, Bategeka et al. (2009) examined the factors that influence birth weight in Uganda using the instrumental variable technique. The findings suggest that birth weight is positively and significantly influenced by the mother's tetanus immunization status, education level, and attendance at antenatal care, but negatively influenced by the smoking of tobacco and malaria infection of the mother.

2.3.1 Other Key determinants of birth weight

Applying the instrumental variable technique to the Botswana Family Health Survey (BFHS) data for 1996, Okurut (2009) found that birth weight is positively and significantly influenced by the mother's socio-economic characteristics (tetanus immunization status, age, and education level) and the husband's education level.

The results from Bategeka (2006) and Okurut (2009) reinforce the role of maternal socio-economic factors and biomedical inputs such as antenatal care services and tetanus vaccination on childhood birth weight. The authors thus suggested that policy should be geared at, improving the education of the girl child and improving access to productive health care. The results conclude that services (tetanus immunization and quality antenatal care) are critical in enhancing the health status of the unborn children in Botswana.

The extensive body of work on factors influencing weight of babies at birth and subsequent weights are quite huge and the intention of this work is to augment the existing body of knowledge. It will also provide further evidence on some of the key factors that determine the nature of growth of baby weights as time progresses.

2.4 Related Works on Growth Models

Generally, in life sciences, the linear growth models do not perform better and the nonlinear models give better estimates. Nonlinear models are estimated by a number of researchers involving mammalian species.

Gompertz (1825) stated that the human death rate is the sum of an age-dependent component which increases exponentially with age. The law rests on a priori assumption that a person' resistance to death decreases as his years increase.

Song et al., (2001) described a process of fitting a Gompertz nonlinear mixed model to longitudinal infancy length data using SAS PROC NLMIXED. The Gompertz model was shown to describe fetal and early infancy growth well. This model was successfully fit to individual weight, length and head circumference data of term and pre-term infants.

Gavrilova and Gavrilov (2015) compared the performance (goodness of fit) of two competing models-the Gompertz model and the logistic (Kannisto) model using data for three mammalian species: 22 birth cohorts of U.S. men and women, eight cohorts of laboratory mice, and ten cohorts of laboratory rats. In all the cases, the Gompertz model showed better fit (lower value of AIC) than the 'mortality deceleration' Kannistol model for both men and women in the studied age interval 80-106 years. The AIC differences between the best (Gompertz) model and the Kannisto model are higher than ten for almost all studied birth cohorts. The researchers concluded that the Gompertz model was significantly better supported by data on U.S. mortality compared with the competing mortality deceleration Kannisto model.

For instance, Sezer and Tarhan (2005) compared the growth features and parameters of three meat-type lines of Japanese quail. The body weight data of wild-type, dotted-white and extended-brown quail lines over time were collected and fitted to Richards's equation.

The important parameters were compared using the Confidence Interval Test in which the overall model predictions for male brown and white quails as well as female brown and wild-type quails indicated the greatest differences. Their research also revealed that males, white and wild females were the closest lines, but their likeliness indicated lower percentage compared to their male counterparts.

Growth curve parameters of body weight and dry matter intake were investigated using Gompertz model and the results showed that there was no significant differences between genotypes for dry matter intake while there existed significant genotypic effect on integration constant, absolute weight gain at birth, degree of maturity at birth and absolute body weight gain from birth to six months of age for body weight (Akbas et al, 2006).

Anthony et al. (1991) estimated growth curves and their parameters used Gompertz, Logistic and Richards models to determine the age-live weight relationships and further examined whether there were breed differences in the growth parameters of two indigenous chicken breeds. Their results showed that the Gompertz growth curve was appropriate for describing the age-live weight relationship in the Venda and Naked Neck Chickens.

CHAPTER THREE

METHODOLOGY

3.1 Overview of methodology

This chapter describes the methodology that was employed in every aspect of this study. It examines the study area, target and study population, the source of data and the data collection procedure, the statistical analysis, modelling approach, model evaluation and profile analysis.

3.2 The Study Area

The research survey was conducted in the Bolgatanga Municipality of the Upper East Region. Bolgatanga is located in the Guinea Savanna zone of Ghana with sparse vegetation dominated by grasses which are mainly grazed by ruminants and trees which are short with much bark to resist perennial bush fires. The Municipality is into commercial activities such as trading, grain processing among others. It has a population of an about 131,550 people of which the number of females is 68,767 and number of males is 62,783. Bolgatanga Municipality is located in the center of the Upper East Region, and is also the regional capital. It has a total land area of 729 sq. km and is bordered to the North by the Bongo District, to the South and East by the Talensi-Nabdam District and the Kassena-Nankana District to the West. It was established by Legislative Instrument 1797 (2004). It is between latitude 10°47'N and longitude 0°51'W. (Wikipedia).

3.3 The Study Population

The study population is made up of 235 babies whose weights were measured in the seven health facilities such as Bolgatanga referral hospital, Coronation Clinic (Plaza), Amiah Hospital, Afrikids Medical Centre, Bolgatanga Health Centre (Aningazanga Health Centre), Zuarungu Health Centre and Asankunde Memorial Clinic under this study in the municipality from 1st January to 31st December 2013.

3.4 Target Population

The target population comprises all babies (300) who were weighed for at least six months in these health facilities from 1st January, to 31st December, 2013. We had secondary data from Bolgatanga referral hospital, Coronation Clinic (Plaza), Amiah Hospital, Afrikids Medical Centre, Bolgatanga Health Centre (Aningazanga Health Centre), Zuarungu Health Centre and Asankunde Memorial Clinic.

3.5 Source of Data and Data Collection

Data was obtained from the seven health facilities by reviewing records of women who delivered both in the referral hospital and the six clinics from January 2013 to December 2013.The data obtained from the registers and the post natal cards on which the birth weights and the subsequent weights of the babies were recorded in kilograms.

The socio-economic/demographic and biological determinants of birth weights in Ghana are generally incomplete on the health registers. Hence, we obtained factors such as maternal age, marital status, and breast feeding type, family planning type, religious affiliation, educational status, parity and occupation by interviewing the nursing mothers. Babies were qualified if their weights were measured for at least six months (half a year) and at most one month absence from consecutive monthly weighing.

Out of 300 weights of babies in kilograms taken, only 235 weights were included in the analysis since 65 of them failed to meet the selection criteria.

3.6 Statistical analysis

The data which was extracted from the post natal records of mothers visiting the health facilities for post natal services for their babies was characterized with some degree of missing data since we had no control on the recording of the weights of the babies throughout the period covered for the study.

The data were sorted and missing values generated by the multiple imputation approach. We then entered the data into Excel spread sheet and imported into Stata 16, SPSS and SAS version 9.2 for analysis. The data will be presented in graphs, tables and charts.

3.7 Modeling Approach

The change in baby weight over time was statistically analysed by the use of the linear fixed effects models, this entailed variables such as sex of baby, breast feeding, mother's age, occupation, marital status, education, religious affiliation, family planning and parity group. This modeling approach takes into account within and between sources of variation and are flexible enough to account for the natural heterogeneity in the population.

If we have the situation in which a t − component response vector is measured for each of n experimental units then we let y_{ij} denote the j^{th} component of the response from subject i for $i = 1, 2, \cdots, n$ and $j = 1, 2, \cdots, t$. Suppose also that y_{ij} is generated from the linear fixed effects model

$$y_{ij} = x'_i\beta_j + e_{ij} \quad _i = 1,2 \ldots\ldots n \tag{3.1}$$

Where;

$$x_i = \left(x_{i1}, x_{i2}, \cdots, x_{ip}\right)'$$

,is a vector of p known coefficients specific to the i^{th} subject and common to the t^{th} component of the response and

$$\beta_j = \left(\beta_{1j}, \beta_{2j}, \cdots, \beta_{pj}\right)',$$

is a vector of p unknown parameters specific to j^{th} time point. The covariance matrix of weights of babies is given as:

$y_{ij} = (y_{i1}, y_{i2}, \cdots, y_{it})'$,

Where y_{ij}

is positive-definite if $p \leq n - t$.

Let $e_i = (e_{i1}, e_{i2}, \cdots, (e_{it})')$

denote the vector of t residuals from the i^{th} subject, and suppose that

$$e_i \sim N_t(0_t, \Sigma) \ .$$

Then $nt \times 1$ vector implies

$e = \begin{pmatrix} e_1 \\ e_2 \\ \vdots \\ e_n \end{pmatrix}$ has the $N_{nt}(0_{nt}, I_n \otimes \Sigma)$ distribution, where I_n denotes the $n \times n$ identity matrix and the operator $\otimes$ denotes the direct (Kronecker) product. The y_i vectors are independent $N_t(\mu_i, \Sigma)$ random vectors with

$$\mu_i = \begin{pmatrix} \mu_{i1} \\ \mu_{i2} \\ \vdots \\ \mu_{it} \end{pmatrix} = \begin{pmatrix} x'_i\beta_1 \\ x'_i\beta_2 \\ \vdots \\ x'_i\beta_t \end{pmatrix}$$

We can express the model in terms of matrices, where Y denotes the $n \times t$ data matrix by;

$$Y = \begin{pmatrix} y_{11} & y_{12} & \cdots & y_{1t} \\ y_{21} & y_{22} & \cdots & y_{2t} \\ \vdots & \vdots & \vdots & \vdots \\ y_{n1} & y_{n2} & \cdots & y_{nt} \end{pmatrix} = \begin{pmatrix} y'_1 \\ y'_2 \\ \vdots \\ y'_t \end{pmatrix}$$

Let X denote the $n \times p$ known design matrix of rank $p \leq n - t$.

$$X = \begin{pmatrix} x_{11} & x_{12} & \cdots & x_{1t} \\ x_{21} & x_{22} & \cdots & x_{2t} \\ \vdots & \vdots & \vdots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{nt} \end{pmatrix} = \begin{pmatrix} x'_1 \\ x'_2 \\ \vdots \\ x'_t \end{pmatrix}$$

Let $\mathcal{B}$ denote the $p \times t$ parameter matrix

$$\mathcal{B} = \begin{pmatrix} \beta_{11} & \beta_{12} & \cdots & \beta_{1t} \\ \beta_{21} & \beta_{22} & \cdots & \beta_{2t} \\ \vdots & \vdots & \vdots & \vdots \\ \beta_{p1} & \beta_{p2} & \cdots & \beta_{pt} \end{pmatrix} = (\beta_1, \beta_2, \cdots, \beta_t).$$

Let E denote the $n \times t$ matrix of random errors E, where:

$$\boldsymbol{E} = \begin{pmatrix} e_{11} & e_{12} & \cdots & e_{1t} \\ e_{21} & e_{22} & \cdots & e_{2t} \\ \vdots & \vdots & \vdots & \vdots \\ e_{n1} & e_{n2} & \cdots & e_{nt} \end{pmatrix} = \begin{pmatrix} e'_1 \\ e'_2 \\ \vdots \\ e'_t \end{pmatrix}$$

We can now write the multivariate general model as

$$\boldsymbol{Y} = \boldsymbol{X\mathcal{B}} + \boldsymbol{E} \tag{3.2}$$

$$\boldsymbol{E}(\boldsymbol{Y}) = \boldsymbol{X\mathcal{B}} \tag{3.3}$$ and

$$Var\begin{pmatrix} y'_1 \\ y'_2 \\ \vdots \\ \vdots \\ y'_t \end{pmatrix} = I_n \otimes \Sigma$$

The initial full model is given as follows;

$$Y_i = \beta_0 + \beta_1 x_i^1 + \beta_2 x_i^2 + \beta_3 x_i^3 + \beta_4 x_i^4 + \beta_5 x_i^5 + \beta_6 x_i^6 + \beta_7 x_i^7 + \beta_8 x_i^8 + \beta_9 x_i^9 + \varepsilon_1 \tag{3.4}$$

Where;

x_i^1 *is sex of the* i^{th} *baby*, x_i^2 is age of the i^{th} *mother*, x_i^3 is educational status of the i^{th} mother, x_i^4 is marital status of the i^{th} mother, x_i^5 is type of breast feeding of the i^{th} family, x_i^6 is occupation of the i^{th} mother, x_i^7 is religion of the i^{th} mother, x_i^8 is Parity group of the i^{th} mother , x_i^9 is type of family planning of the i^{th} family , β_0 is a fixed-effect intercept that varies according to i, which is the baby's index, t is the time in months and has the value 0 (at the start of follow-up), 1(at 1 months after start of the baby weight), 2 (at 2 months after start), 3 (at 3 months after start),….. The resulting estimated ***b's***, the fixed-effect parameter for each predictor in these models, represents the average change in baby weight for a unit increase in that predictor. In the second stage of this model, the relationship between different baby weights over time is defined.

We estimated a co-variance and correlation matrix to determine which particular covariance model best fits the data (Michael, 2002).

3.7.1 Correlation and Covariance Structure

In discussing the correlation, we examined the component of variance that could enable us find a variance or correlation model for regression in our mixed-fixed model. To do this, we estimate the covariance matrix which is written in terms of σ_j^2 and the correlation ρ_{jk} such that;

$$Cov(Y_i)= \begin{bmatrix} \sigma_1^2 & \sigma_1\sigma_2\rho_{12} \ldots\ldots \sigma_1\sigma_n\rho_{1n} \\ \sigma_2\sigma_1\rho_{21} & \sigma_2^2 \quad \ldots \sigma_2\sigma_n\rho_{2n} \\ \sigma_n\sigma_1\rho_{n1} & \sigma_n\sigma_2\rho_{n2} \ldots . \sigma_n^2 \end{bmatrix} \tag{3.6}$$

$$And \;\; Corr(Y_i) = \begin{bmatrix} 1 & \rho_{12} \ldots\ldots \rho_{1n} \\ \rho_{21} & 1 \ldots\ldots \rho_{2n} \\ \rho_{n1} & \rho_{n2} \ldots . 1 \end{bmatrix} \tag{3.7}$$

which is useful for comparing the strength of association between each pair of outcomes particularly when the variance is not constant (Sawalha, 2005).

3.7.2 Model for Covariance Structure

Different covariance structures are possible in longitudinal analysis of data based on how pairs of observations are found to be related. Some of these structures are: autoregressive, compound symmetry, variance components and ARMA (1, 1).

3.7.2.1 Autoregressive (1)

The Autoregressive 1(AR (1)) structure has homogeneous variances and correlations that decline exponentially with distance. Two measurements that are right next to each other in time are pretty correlated (depending on the value of ρ), but as measurements get farther and farther apart they are less correlated.

$$Corr(Y_i) = \begin{pmatrix} 1 & \rho & \rho^2 & \rho^3 \\ \rho & 1 & \rho & \rho^2 \\ \rho^2 & \rho & 1 & \rho \\ \rho^3 & \rho^2 & \rho & 1 \end{pmatrix} \tag{3.8}$$

3.7.2.2 Compound Symmetry

The compound symmetry has a correlation between two separate measurements, but it is assumed that the correlation is constant regardless of how far apart the measurements are.

$$Corr(Y_i) = \begin{pmatrix} \sigma^2 + \sigma_1^2 & \sigma_1^2 & \sigma_1^2 & \sigma_1^2 \\ \sigma_1^2 & \sigma^2 + \sigma_1^2 & \sigma_1^2 & \sigma_1^2 \\ \sigma_1^2 & \sigma_1^2 & \sigma^2 + \sigma_1^2 & \sigma_1^2 \\ \sigma_1^2 & \sigma_1^2 & \sigma_1^2 & \sigma^2 + \sigma_1^2 \end{pmatrix} \tag{3.9}$$

3.7.2.3 Variance Components

The variance covariance structure is the standard variance components, where there is no correlation between any pair of observations. The covariance structure is given as;

$$Corr(Y_i) = \begin{pmatrix} \sigma_A^2 & 0 & 0 & 0 \\ 0 & \sigma_B^2 & 0 & 0 \\ 0 & 0 & \sigma_{AB}^2 & 0 \\ 0 & 0 & 0 & \sigma_{AB}^2 \end{pmatrix} \tag{3.10}$$

3.7.2.4 ARMA (1, 1)

The measurements are repeated across time, then the time variable will be prominent in this distance function. If measurements are repeated across location, then the distance function will involve some spatial metric reflecting the experimental design's geometry.

$$Corr(Y_i) = \begin{pmatrix} \sigma^2 & \sigma^2\lambda & \sigma^2\lambda\rho & \sigma^2\lambda\rho^2 \\ \sigma^2\lambda & \sigma^2 & \sigma^2\lambda & \sigma^2\lambda\rho \\ \sigma^2\lambda\rho & \sigma^2\lambda & \sigma^2 & \sigma^2\lambda \\ \sigma^2\lambda\rho^2 & \sigma^2\lambda\rho & \sigma^2\lambda & \sigma^2 \end{pmatrix} \tag{3.11}$$

The regression parameter β and the covariance parameters are obtained by maximizing the likelihood function;

$$L \propto (\sigma^2)^{-N/2} \prod_i |W_i|^{1+2} \times exp\left\{\sum_i \frac{-1}{2\sigma^2}(y_i - X_i\beta)^T W_i (y_i - X_i\beta)\right\}$$

where ; $\prod_i$ *is multiplication from* $i = 1$ *to* N,

$W_i = (\sigma^{-2} Z_i \psi Z_i^T + I)^{-1}$, given the covariance parameters, L is maximized at Generalized Least Square estimate (Jianqing, 1999).

$$\hat{\beta} = \left(\sum_{i=1}^{m} X_i^T W_i X_i\right)^{-1} \left(\sum_{i=1}^{m} X_i^T W_i y_i\right) \tag{3.12}$$

3.8 Model selection for covariance structures

Akaike's information criterion (AIC) and Bayesian Information Criterion (BIC) are indices of relative goodness-of-fit and may be used to compare models with the same fixed effects but different covariance structures. Both of these criteria apply rather generally for purposes of model selection and hypothesis testing. Formulae for their computation are

$$AIC = L(\hat{\theta}) - q \tag{3.13}$$

$$BIC = L(\hat{\theta}) - (q + 2)\, log(N^*) \tag{3.14}$$

where $L(\hat{\theta})$ is the maximized log-likelihood or restricted log-likelihood (REML), q is the number of parameters in the covariance matrix, p is the number of fixed effect parameters and N is the number of subjects; (N for ML and $N - p$ for REML).

Models with smaller AIC or BIC values indicate a better fit. However, it is important to note that the BIC criterion penalizes models more severely for the number of estimated parameters than AIC does. Hence the two criteria will not always agree on the choice of best model. Since our objective is parsimonious modeling of the covariance structure, hence BIC is more reliable than the AIC criterion.

3.9 Model Evaluation

The null hypothesis for both tests is that the smaller model is the true model; a big test statistic (in relation to level of significance) shows that the null hypothesis is false. The test obtain values for the coefficients or parameter estimates which makes the value of the likelihood function a maximum. This research uses the log of the likelihood instead of the likelihood itself. For instance, if the log of the likelihood function in the test gives a negative value and large values approximately equal to zero, it best fits the model.

Such tests identify values for the parameters (coefficients) that increase the value of the likelihood function. We apply the log of the likelihood, rather than the likelihood itself, because it is simpler and easier to work with. In the test, if the log likelihood proves to be negative, with greater values approximately equal to zero and it will better fit the model since it is simpler and easier to work with.

3.10 The Likelihood Ratio Test (LRT)

This model is constructed by estimating the two models and comparing their fitness. After comparing the likelihood of their models and there is significant difference, the model with a lot of variables will fit the data significantly better compared to the more restrictive one. Therefore, the formula for the LR test statistic is given as:

$$T_{LRT} = -2\left(log\hat{L}_{reduced} - log\hat{L}_{full}\right) = 2log\hat{L}_{full} - 2log\hat{L}_{reduced} \qquad (3.15)$$

The test statistic is distributed by chi-square, with degree of freedom equal to the number of parameters.

3.11 The Wald Test

The Wald test, tests the null hypothesis that a set of two parameters are simultaneously equal to zero. When the test fails to reject the null hypothesis, it implies that a substantial removal of the variables from the model will not adequately affect the fit of the model.

3.12 Profile Analysis

The pattern of mean change in baby weight is portrayed through the profile analysis. We carried out profile plot to observe the trajectory of change in baby weight over time. The following Covariates were used for the plot; sex of the baby, marital status, breast feeding, maternal educational level, family planning type employed by the mother, and mother's religious affiliation. We constructed profiles for the means of baby weight $(\bar{x}_0, \bar{x}_1, \bar{x}_2, \ldots, \bar{x}_6)$ against the time points $t = 0, 1, 2, \ldots., 12$ for the various groups.

Then a scatter plot for the means of average change in weights of babies over time was performed and the pattern fitted. We went ahead and fitted a linear trend for the pattern.

AIC and BIC were used to select the best growth model that was fitted for prediction of the trend model.

3.13 MANOVA

Multivariate Analysis of variance (MANOVA) was performed to complement and confirm the profile plot of test of parallelism. The MANOVA test depends on the equations:

Wilks' Lambda (Λ^*) $= \frac{|W|}{|B+W|}$

Lawley-Hotelling Trace = $tr[BW^{-1}]$, Pillai trace = $tr[B(\acute{B} + W)^{-1}]$

Roy's largest root = maximum eigenvalue of $B(B+W)^{-1}$

Where $W = \sum_{i=1}^{g} \sum_{j=1}^{nl} (X_{ij} - \bar{X}_l)\,(X_{ij} - \bar{X}_l)'$ (3.16)

$B = \sum_{i=1}^{g} n_l (X_{ij} - \bar{X}_l)(X_{ij} - \bar{X}_l)'$ (3.17)

3.14 Test of Parallel profiles

Parallelism exists in profiles when group differences are constant across variables. We calculated the difference of successive variables for each variable in each group and did the two-sample Hoteling's T^2 test.

Hypothesis

$$H_0 : C\vec{\mu}_x = C\vec{\mu}_y \quad \text{vs}$$
$$H_A : C\vec{\mu}_x \neq C\vec{\mu}_y$$

The null hypothesis states that the mean weights of the babies are similar or parallel whilst the alternative states that the mean weights of the babies are not similar or parallel.

Let $\vec{x}_1, \vec{x}_2, \ldots, \vec{x}_n$ be the means of baby weight at the various time points of one level of a group of a sample of *g* from the *p*-variate normal distribution with mean vector $\overrightarrow{\mu_x}$ and covariance matrix S.

Let $\vec{y}_1, \vec{y}_2, \ldots, \vec{y}_m$ be the means of baby weight at the various time points of another level of a group of a sample of *h* from the *p*-variate normal distribution with mean vector $\overrightarrow{\mu_y}$ and covariance matrix **S**.

Let

$$\underset{(p-1)\times p}{C} = \begin{bmatrix} 1 & -1 & 0 & 0 & \cdots & 0 & 0 \\ 0 & 1 & -1 & 0 & \cdots & 0 & 0 \\ 0 & 0 & 1 & -1 & \cdots & 0 & 0 \\ 0 & 0 & 0 & 1 & \cdots & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & 0 & 0 & 0 & \cdots & 1 & -1 \end{bmatrix} \quad (3.18)$$

Then

$$C\vec{X} = C\begin{bmatrix} X_1 \\ \vdots \\ X_p \end{bmatrix} = \begin{bmatrix} X_1 - X_2 \\ X_2 - X_3 \\ \\ X_{p-1} - X_p \end{bmatrix}$$

3.15 Test of Equality of Groups (Parallelism assumed)

If parallelism is proven, it is appropriate to test for equality of profiles, by the

$$H_0: C'\mu_1 = C'\mu_2 = C'\mu_3 = \cdots = C'\mu_n$$

$$H_A: C'\mu_1 \neq C'\mu_2 \neq C'\mu_3 \neq \cdots \neq C'\mu_n$$

OR

H_0: There is no difference between the levels of a factors

H_1: There is a difference between at least one level and the others

To perform this test of equality of groups, average all the variables for each case in each group is found and the two-sample $t - test$

$$\boldsymbol{T^2 = C'\,(\bar{X}_1 - \bar{X}_2)\left[\left(\frac{1}{n_1} + \frac{1}{n_2}\right) C' S_{pooled} C\right]^{-1} C'\,(\bar{X}_1 - \bar{X}_2)} \qquad (3.19)$$

$$= \left(\frac{\boldsymbol{C'\,(\bar{X}_1 - \bar{X}_2)}}{\sqrt{\left(\boldsymbol{\frac{1}{n_1} + \frac{1}{n_2}}\right) \boldsymbol{C' S_{pooled} C}}}\right)^2 > t^2_{n1+n2-2(\alpha/2)} = F_{1,n1+n2-2(\alpha)}$$

Thus we reject H_0 if $|t| > t_{\alpha+2}$with $df = n1 + n2 - 2$. If equality of groups is observed, then we can go ahead to check for flatness.

$$\underset{(p-1)\times p}{C} = \begin{bmatrix} 1 & -1 & 0 & 0 & \cdots & 0 & 0 \\ 0 & 1 & -1 & 0 & \cdots & 0 & 0 \\ 0 & 0 & 1 & -1 & \cdots & 0 & 0 \\ 0 & 0 & 0 & 1 & \cdots & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & 0 & 0 & 0 & \cdots & 1 & -1 \end{bmatrix} \qquad (3.20)$$

Let

$$\text{Then } C\vec{X} = C\begin{bmatrix} X_1 \\ \vdots \\ X_p \end{bmatrix} = \begin{bmatrix} X_1 - X_2 \\ X_2 - X_3 \\ \\ X_{p-1} - X_p \end{bmatrix} \tag{3.21}$$

3.16 Test of Flatness of Variables

Basically the average of each segment across groups is used to compute this and each score has zero subtracted from, is squared and divided by the pooled error SSCP matrix (Swg).

$$T^2 = n\left(C\vec{\bar{x}} - \vec{0}\right)'\left(CS_{pooled}C'\right)^{-1}\left(C\vec{\bar{x}} - \vec{0}\right) \tag{3.22}$$

$$= n\left(C\vec{\bar{x}}\right)'\left(CS_{pooled}C'\right)^{-1}\left(C\vec{\bar{x}}\right)$$

If H_0 is true then

$$F = \frac{n-p+1}{(p-1)(n-1)}T^2 \tag{3.23}$$

has a F distribution with $v_1 = p - 1\ and\ v_2 = n - p + 1$, thus we reject H_0 if $F > F_\alpha$ with $v_1 = p - 1$

3.2 Growth model

Apart from using the profile analysis to examine and assess repeated measurements which assumes a linear model framework we can also assess growth models using the non-linear approach. The most popular of them are the Gompertz and logistic models (Winsor, 1932).

3.2.1 Gompertz growth model

These models can have three or four parametric models but in this study we used the three parameter growth models in our analysis.

The Gompertz 3-parametric growth model is given by; Given that

$$y = ke^{-e^{-\alpha(x-\beta)}} \qquad (3.24)$$

We can write this as

$$y = ke^{-e^{(\mu-\alpha x)}} \qquad (3.25)$$

where $\mu = \alpha\beta$, y = mean weights of babies and x = time in months

3.2.1.1 Growth rate of mean weights of babies

To find $\frac{dy}{dx}$ from (3.25), we used the chain rule by letting

$$t = -e^{(\mu-\alpha x)} \qquad (3.26)$$

and

$$y = ke^{t} \qquad (3.27)$$

From (3.26), $\frac{dt}{dx} = -\alpha(-e^{(\mu-\alpha x)}) = \alpha e^{(\mu-\alpha x)}$ (3.28)

and from (3.27), $\frac{dy}{dt} = ke^{t}$ (3.29)

$$\frac{dy}{dx} = \frac{dt}{dx}.\frac{dy}{dt} = ke^{t}\left(\alpha e^{(\mu-\alpha x)}\right) = \alpha y e^{(\mu-\alpha x)} \qquad (3.30)$$

From (3.25), we divided both sides by k and took logarithms of both sides and got

$$\log\left(\frac{y}{k}\right) = -e^{(\mu-\alpha x)} \qquad (3.31)$$

Dividing through by -1 implies

$$\log\left(\frac{k}{y}\right) = e^{(\mu-\alpha x)} \tag{3.32}$$

Substituting (3.32) into (3.30) implies

$$\frac{dy}{dx} = \alpha y e^{(\mu-\alpha x)} = \alpha y \log\left(\frac{k}{y}\right) \tag{3.33}$$

From (3.33), the relative growth rate of mean weights of babies as a function of time is :

$$\frac{1}{y}\frac{dy}{dx} = \alpha e^{(\mu-\alpha x)} \tag{3.34}$$

Also from (9), the relative growth rate of mean weights of babies as a function of size is:

$$\frac{1}{y}\frac{dy}{dx} = \alpha(\log k - \log y) \tag{3.35}$$

To find the $x - coordinate$, we equated (3.30) to zero i.e.

$$\alpha y e^{(\mu-\alpha x)} = 0 \tag{3.36}$$

Solving (3.36) gave $x = \frac{\mu}{\alpha}$ when put into (2) gave $y = \frac{k}{e}$

Testing for nature of stationary points

From (3.30) ,

$$\frac{dy}{dx} = \alpha y e^{(\mu-\alpha x)}$$

Using the product rule, let

$$m = y = k e^{-e^{(\mu-\alpha x)}}$$

and $$n = \alpha e^{(\mu-\alpha x)}$$

Then, $$\frac{dm}{dx} = \alpha y e^{(\mu - \alpha x)}$$

and

$$\frac{dn}{dx} = -\alpha^2 e^{(\mu - \alpha x)} \tag{3.37}$$

but $\frac{d^2y}{dx^2} = m\frac{dn}{dx} + n\frac{dm}{dx} = y\left(-\alpha^2 e^{(\mu-\alpha x)}\right) + \alpha e^{(\mu-\alpha x)}\left(\alpha y e^{(\mu-\alpha x)}\right)$

$$= \alpha^2 y e^{(\mu-\alpha x)}\left(e^{(\mu-\alpha x)} - 1\right) \tag{3.38}$$

To test for the nature of stationary point, we put $x = \frac{\mu}{\alpha}$ into (3.38) i.e

$$\frac{d^2y}{dx^2} = \alpha^2 y e^{(\mu-\alpha x)}\left(e^{\left(\mu-\alpha\left(\frac{\mu}{\alpha}\right)\right)} - 1\right) = 0$$

$$Since \quad \frac{d^2y}{dx^2} = 0$$

the point of inflexion of mean weights of babies occurred at $x = \frac{\mu}{\alpha}$.

The ordinate at the point of inflexion is $y = \frac{k}{e}$ .The maximum growth rate of mean weights of babies in the municipality from (3.30) is $\frac{dy}{dx} = \alpha y e^{(\mu-\alpha x)}$. But $y = \frac{k}{e}$ and $x = \frac{\mu}{\alpha}$ when put into (3.30) gave a maximum growth rate of mean weights of babies in the municipality as:

$(\frac{dy}{dx}) = \frac{\mu k}{e}$, asymptotes occurred at y = 0 and y = k

From practice, we fit Gompertz growth model if the point of inflexion is about 35-40% of the total growth attained.

3.2.2 Logistic growth model

We can also fit a logistic growth model for our data which is a close counterpart of the Gompertz model. The logistic model is given by;

$$y = \frac{k}{(1+e^{-\alpha(x-\beta)})} \tag{3.39}$$

which can be rewritten as

$$y = \frac{k}{1+e^{(\mu-\alpha x)}} = k(1 + e^{(\mu-\alpha x)})^{-1} \tag{3.40}$$

$where\ \mu = \alpha\beta$

3.2.2.1 Growth rate of mean weights of babies

To find $\frac{dy}{dx}$, from (3.40) we used the chain rule by letting

$$t = 1 + e^{(\mu-\alpha x)} \tag{3.41}$$

and $y = kt^{-1}$ (3.42)

From (3),

$$\frac{dt}{dx} = -\alpha e^{(\mu-\alpha x)} \tag{3.43}$$

Also from

$$\frac{dy}{dt} = -kt^{-2} \tag{3.44}$$

But

$$\frac{dy}{dx} = \frac{dt}{dx} \cdot \frac{dy}{dt} = -kt^{-2}(-\alpha e^{(\mu-\alpha x)}) = k\alpha e^{(\mu-\alpha x)}t^{-2} \tag{3.45}$$

From (3.39),

$$e^{(\mu-\alpha x)} = \frac{k-y}{y} \tag{3.46}$$

Substituting (3.46) into (3.45) gives

$$\frac{dy}{dx} = \frac{\alpha y}{k}(k-y) \tag{3.47}$$

The maximum growth rate of mean weights of babies is $\frac{\alpha k}{4}$,

asymptotes occurred at y = 0 and y = k

Point of inflexion occurred at $x = \frac{\mu}{\alpha}$ and $\frac{k}{2}$.

The relative growth of mean weights of babies as a function of time is given by:

$$\frac{1}{y}\frac{dy}{dx} = \frac{\alpha}{1+e^{-\mu+\alpha x}} \tag{3.48}$$

The relative growth rate of mean weights of babies as a function of size is given by :

$$\frac{1}{y}\frac{dy}{dx} = \frac{\alpha}{k}(k-y)$$

The principal interest in the two models is to compare them and choose the one which is superior in terms of its ability to provide prediction with the least errors

Where:$e = Euler's\ constant \sim 2.72$.

CHAPTER FOUR

ANALYSIS AND DISCUSSION OF RESULTS

4.0 Introduction

This chapter consists of descriptive statistics of weights of babies under the study, preliminary analysis, and profiles of maternal and biological factors and further analysis on trend models as well as the mixed model.

4.1 Preliminary Analysis

Table 4.1displays the descriptive statistics of characteristic of mother and gender of baby as presented below.

Table 4.1: Distribution of characteristic of mother and gender of baby

Variable	Freq.	Percent	Variable	Freq.	Percent
Mother's age group			**Education**		
17-24	66	28.090	None	27	11.490
25-32	132	56.170	Primary	40	17.020
33+	37	15.740	JHS	66	28.090
			SHS	51	21.700
Breastfeeding			Tertiary	51	21.700
Exclusive	138	58.720	Parity group		
Mixed	48	20.430	1	119	50.640
Nonexclusive	49	20.850	2-3	98	41.700
			4-5	18	7.660
Occupation			Marital status		
Unemployed	33	14.040	Single	34	14.470
Student	15	6.380	Married	201	85.530
Self employed	136	57.870			
Government	51	21.700	Religion of mother		
			Christianity	173	73.620
Gender			Islamic	36	15.320
Male	130	55.320	Traditional	26	11.060
Female	105	44.680			

Mothers who belonged to the age group of 25-32year were 132 representing approximately 56%, those between 17-24years were 66 with a percentage of approximately 28 whilst maternal age group 33years and above were 37 corresponding to an estimated percentage of 16.

Mothers who attained Junior High School level of education emerged the highest with a value of 66 with an estimated percentage of 28, those who completed Senior High School as well as parents who got tertiary education recorded the same figure of 51 indicating an estimated percentage of 22 each. Forty of the mothers completed primary school representing an approximate percentage of 17 whilst 27 mothers did not receive any formal level of education with an estimated percentage of 11.

Mothers who practiced exclusive breast feeding were 138 giving an estimated percentage of 59 compared to 49 and 48 mothers who did nonexclusive breast feeding and mixed (breast milk and water only)respectively.

Mothers who had given birth the first time were 119 relative to 98 and 18 mothers who delivered between 2-3 and 4-5 respectively.

Out of a total of 235 mothers, 136 of them were self-employed with an estimated percentage of 57.870, mothers who were government employees had approximately 21.700 percent, and those who were not employed indicated an approximated percentage of 14 whilst 15 parents were students indicating an estimated percentage of 6.

Majority (130) of the babies whose weights were measured were males whilst the rest (105) were females.

A total of 173 mothers were Christians representing approximately 74 percent whilst 36 were Muslim (i.e. 15 percent) and 26 practiced traditional religion (i.e. 11 percentage).

Table 4.2: Summary statistics of baby weights over time (in months)

Time (month)	Mean	Sd	Min	Max
0	2.723	0.460	1.200	4.200
1	4.161	0.978	1.200	7.000
2	4.949	1.073	1.500	8.000
3	5.730	1.067	2.300	9.000
4	6.342	1.123	2.400	9.500
5	6.849	1.099	3.000	10.000
6	7.135	1.194	3.000	12.000
7	7.432	1.147	3.400	12.600
8	7.732	1.184	4.500	11.500
9	8.018	1.158	5.500	14.000
10	8.422	1.230	5.800	14.000
11	8.760	1.242	6.200	13.000
12	9.605	1.116	6.400	13.300
Total	6.758	2.170	1.200	14.000

Table 4.2 presents the descriptive statistics of mean weights of babies included in the study. The mean weight of babies at birth was 2.72 kg with standard deviation of 0.46 kg. The minimum and maximum weights at birth were 1.20kg to 4.20 kg respectively.

That of the average weight of a twelve month (i.e. one year) old baby was 9.61 kg with standard deviation of approximately 1.12 kg .The minimum and maximum weight values at one year of age was 6.40 kg and 13.30 kg respectively. It is observed that the mean change in weights of the babies at a one year period did not all follow an increasing pattern overtime and that the weight of a baby does not necessarily depend on when the individual was born.

Table 4.3 displays the summary statistics of baby weights by gender over the period of observation.

Table 4.3: Summary statistics of baby weights over time (in months) by sex

Month	Mean		Sd		Minimum		Maximum	
	Male	Female	Male	Female	Male	Female	male	Female
0	2.71	2.74	0.45	0.48	1.30	1.20	4.20	4.10
1	4.18	4.13	0.98	0.98	1.80	1.20	6.60	7.00
2	4.91	4.99	1.10	1.04	1.90	1.50	8.00	7.10
3	5.73	5.73	1.08	1.06	2.30	3.10	9.00	8.20
4	6.29	6.40	1.16	1.07	2.40	3.10	9.50	9.00
5	6.78	6.93	1.13	1.06	3.00	4.00	10.00	10.00
6	7.17	7.09	1.15	1.25	3.00	3.50	11.50	12.00
7	7.41	7.46	1.10	1.21	4.20	3.40	12.60	11.00
8	7.74	7.72	1.20	1.17	4.60	4.50	11.00	11.50
9	8.01	8.03	1.08	1.26	5.50	5.80	11.20	14.00
10	8.37	8.49	1.16	1.31	6.00	5.80	12.00	14.00
11	8.68	8.85	1.11	1.39	6.50	6.20	12.00	13.00
12	9.61	9.60	0.98	1.27	6.90	6.40	11.60	13.30

Table 4.3 displays the means, standard deviation, minimum and maximum weights of babies sampled overtime. The mean birth weight for males was 2.71 kg and that for

females was 2.74 kg. Male babies had the lowest mean birth weight 2.71kg but highest mean weight at age one year 9.61kg as compared to female babies who recorded highest mean birth weight 2.74kg but lowest weight 9.60kg at age one year respectively. The standard deviations of male babies at birth were 0.45 kg and that of female babies was 0.48 kg respectively. The minimum weights at birth were 1.30kg for males and 1.20 kg for females and those of their maximum weights were 4.20 kg and 4.10 kg respectively. Although female babies were heavier at birth, they gave the least minimum and maximum weights at birth with a greater standard deviation compared to that of males. The mean weights of one year old babies (average weight at month twelve) showed that males were 9.61kg which is greater than that for females who weighed 9.60 kg. The standard deviation of 0.98 kg less than that which is 1.27 kg of girls. Males had mean minimum weight at month twelve of 6.90 kg which is greater than that for females (i.e. 6.40 kg) of females within the same period. The mean one year maximum weight for males of 11.60kg was less than that for females which is13.30kg.The mean weights of females at birth (i.e. month zero) are higher compared to the mean weights of boys at birth but lower at the twelve month for females compared to that for males at the same period.

The mean weights of females at birth (i.e. month zero) are higher compared to the mean weights of boys at birth but lower at the twelve month for females compared to their male counterparts at one year old (month twelve). Both sexes at birth however recorded higher mean weights compared to the World Health Organization standard for normal weight of a baby at birth (i.e. 2.50 kg).

Table 4.4 Matrix of Correlation Structure of weights of babies

	0	1	2	3	4	5	6	7	8	9	10	11	12
0	1												
1	0.38	1											
2	0.30	0.47	1										
3	0.25	0.43	0.60	1									
4	0.17	0.32	0.47	0.76	1								
5	0.24	0.33	0.44	0.62	0.70	1							
6	0.23	0.27	0.37	0.63	0.70	0.77	1						
7	0.17	0.26	0.38	0.59	0.65	0.70	0.79	1					
8	0.16	0.27	0.36	0.55	0.61	0.65	0.71	0.74	1				
9	0.17	0.21	0.30	0.49	0.54	0.66	0.73	0.73	0.75	1			
10	0.13	0.18	0.18	0.31	0.33	0.44	0.52	0.54	0.48	0.65	1		
11	0.06	0.09	0.14	0.30	0.30	0.34	0.41	0.38	0.38	0.44	0.36	1	
12	0.01	-0.02	-0.01	-0.04	-0.04	-0.01	0.00	0.04	0.08	0.03	0.06	-0.02	1

Table 4.4 presents the matrix of the correlation structure of the weights of babies sampled in Bolgatanga municipality. From the statistics for variance covariance structure on table 4.13, the model followed the pattern of autoregressive first moving average (ARMA (1, 1).

4.2 Profile Analysis

This section shows and explains the exploratory profile plots of weights of babies by groups as well as outputs of tables obtained from statistical methods such as mixed models, multivariate analysis of variance, Gompertz and Logistic models and the significance of the parameters to the study.

4.2.1 Profile plots of weights of babies by groups

Figure 4.1 indicates the change in weights of babies by breast feeding types over time.

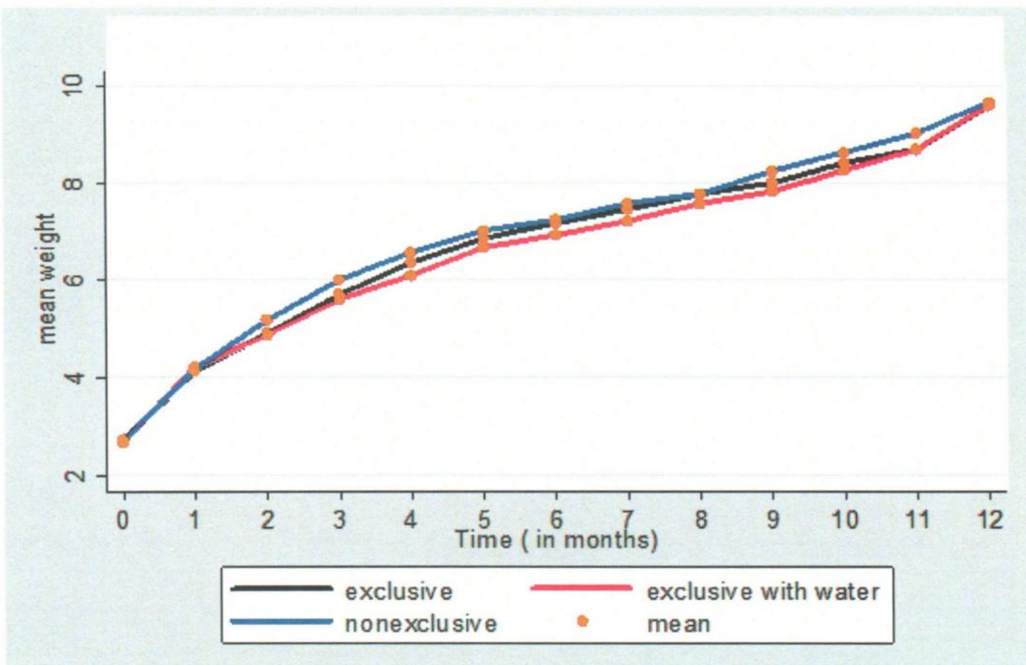


Figure 4.1 Profile plot of mean baby weights by breastfeeding type

The profiles plot in figure 4.1 shows that the mean change in weights of babies over the period of observation for breast feeding type, varied over time with nearly the same pattern. This implies that the average change in weights of babies within breast feeding type may be parallel or similar.

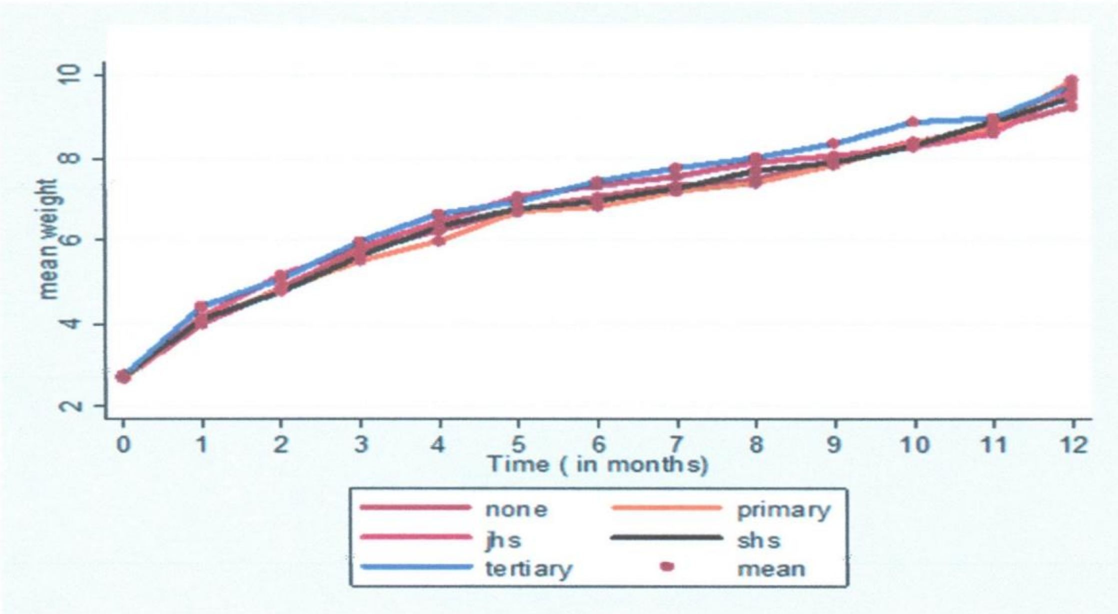


Figure 4.2 Profile plot of mean baby weights by mother's education

Figure 4.2 indicates the mean change in weights of babies by maternal educational level over time. The profiles show that the average changes in weights of babies among the different levels of maternal education were changing over time and the pattern was about the same. This suggests that the mean change in weights of babies may be similar.

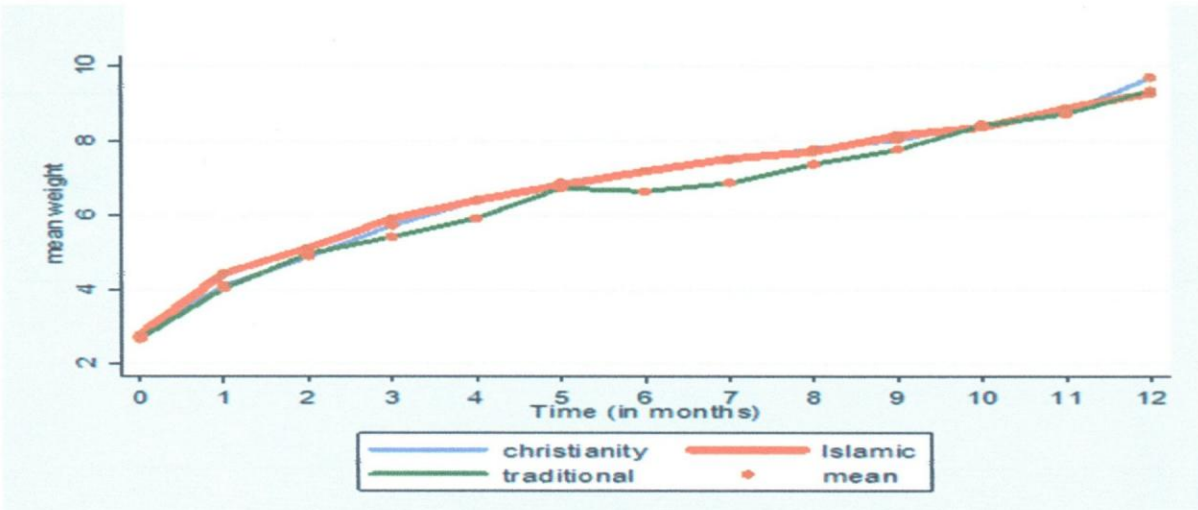


Figure 4.3 Profile plot of mean baby weights by religion

The profiles indicate the mean change in weights of babies against time in respect of their maternal religious affiliation. A similar pattern is observed for all their religious affiliations. It gives the impression that the average change in weights of babies across maternal religious denomination could be similar or parallel.

Figure 4.4 shows the pattern of change in weights of babies over the period of observation for the last type of contraceptive that the mother stopped using before pregnancy. The contraceptives types are injection, norplant, pills, natural and condom. Those who never used contraceptives were also noted.

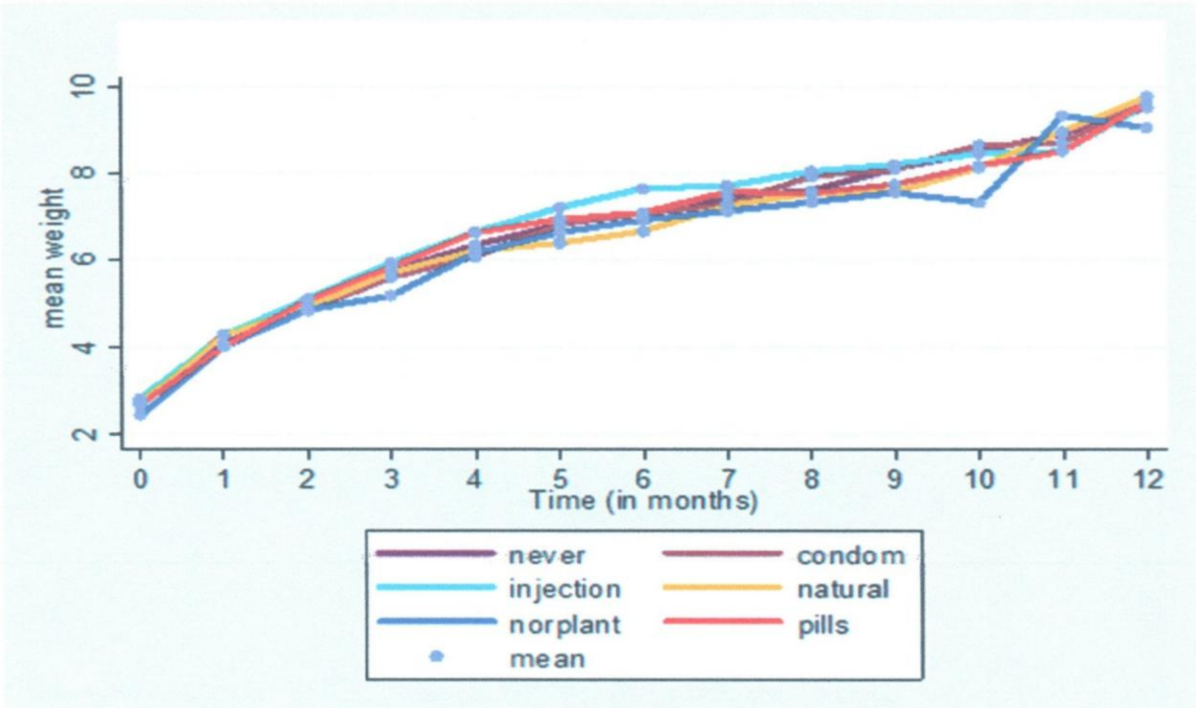


Figure 4.4 Profile plot of mean baby weight by contraceptive use

Apart from the norplant which showed a drop in weight of babies in their 9th to 10th month and a sharp rise in weight from the 10th onto the 11th month and a subsequent drop afterward, the mean change in weights of babies was almost the same over the period of observation. This suggests that apart from norplant, the other contraceptives used by mothers may be similar.

The pattern of change in mean weights of babies over time for mother's age group is displayed in figure 4.5.

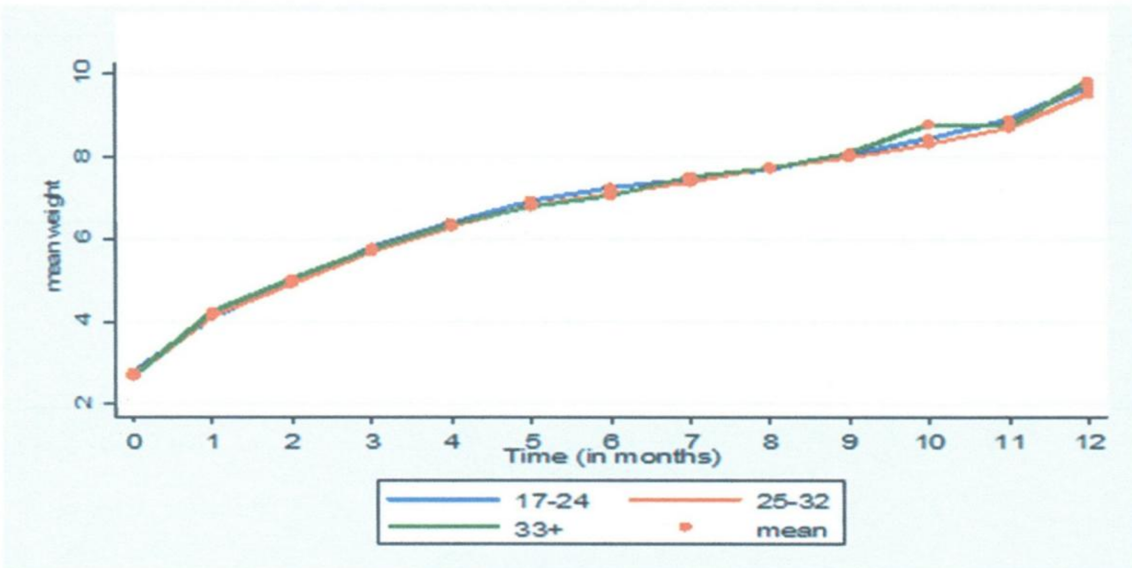


Figure 4.5 Profile plot of mean baby weight by mother's age group

The profiles show that the mean change in weights of babies for mother's age group is changing over time and they had about the same pattern. This implies that the mean change in weights of babies across the mother's age groups was similar or parallel.

The pattern of change in mean weights of babies over time for mother's occupation is shown in figure 4.6.

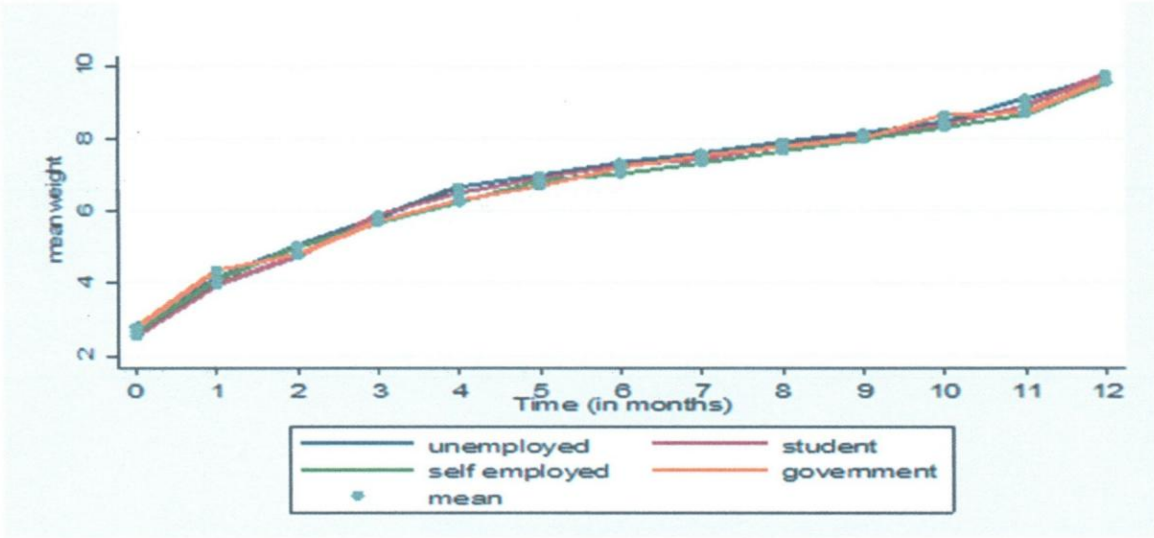


Figure 4.6 Profile plot of mean baby weight by mother's occupation

The profile plot of the maternal occupation in figure 4.6 shows the pattern of average change in weights of babies increased over the period of observation for each of the mother's occupation categories and varied in about the same pattern., according to mother's occupation. It suggests that the mean change in weights of babies within maternal occupation could be similar.

The pattern of change in mean weights of babies over time for parity group is shown in figure 4.7

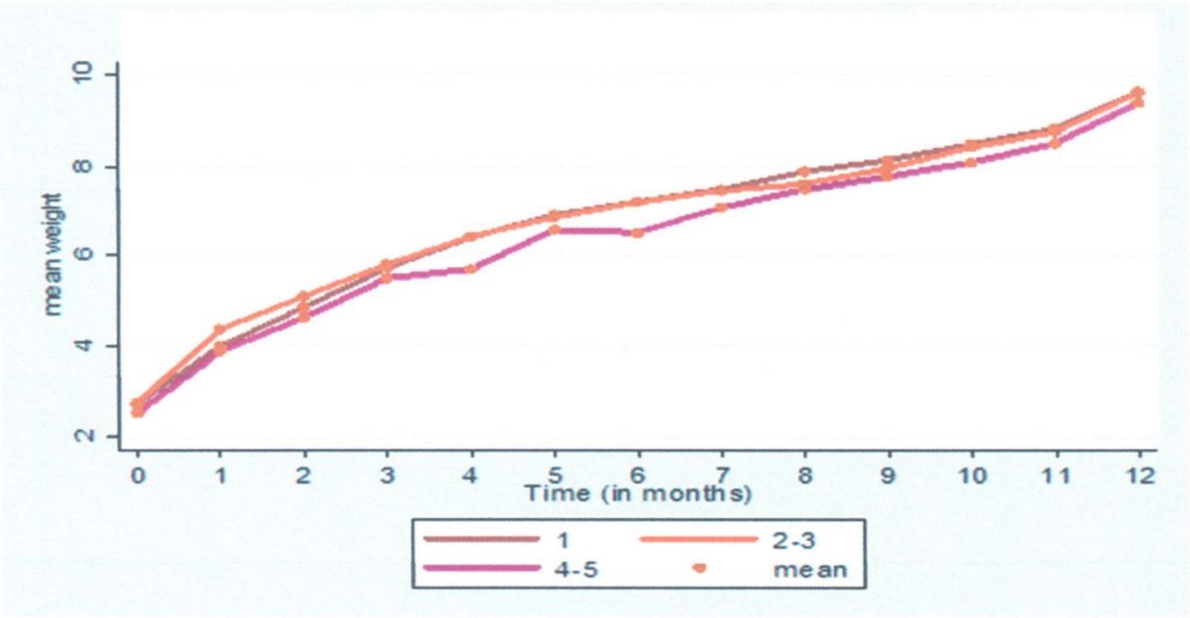


Figure 4.7 Profile plot of mean baby weight by parity group

The profiles indicate that the average change in weights of babies for each parity group increased are changing over time and the change in each was the same except mothers who gave birth four to five times.This gives the impression that the average change in weights of babies within parity group might be similar or parallel for mothers who delivered once and those who gave birth two tot three times.

Figure 4.8 shows the pattern of change in mean weights of babies over time for gender. The figure shows that the mean change in weights of babies for both male and female is changing over time. The variations were about the same pattern. This means that the mean change in weight of babies whether male or female may be similar.

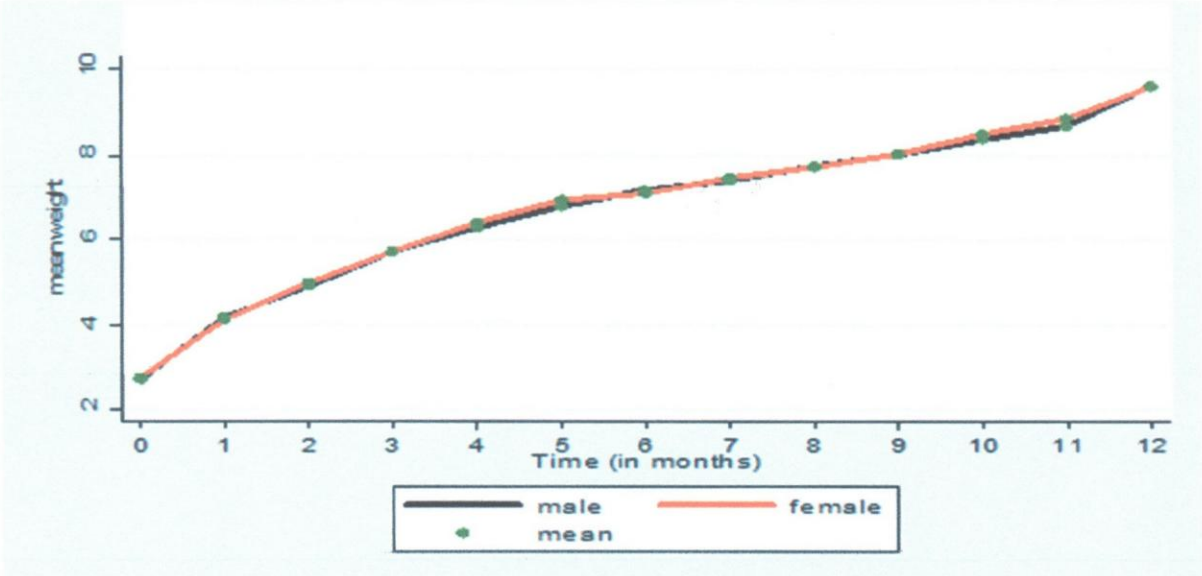


Figure 4.8 Profile plot of mean baby weights by gender

4.2.2 MANOVA Test for Groups

The results of the multivariate analysis of variance test for the mean weights of babies for the groups is shown in Table 4.5 below. The tests suggest that the profiles for the different levels which are: of maternal educational status, the last type of family planning method the mother stopped using before pregnancy, marital status, maternal occupational status and maternal religious affiliation, significantly differed at the 5% significance level and therefore their profiles could be said to be parallel.

Table 4.5 Multivariate Analysis of Variance Test for Groups

Variable	Value	F Value	Pr > F	Variable	Value	F -Value	Pr > F
Sex of baby				**Marital Status**			
Wilks' Lambda	0.9237	1.2800	0.2295	Wilks' Lambda	0.7644	4.7700	0.0000
Pillai' Trace	0.0763	1.2800	0.2295	Pillai' Trace	0.2356	4.7700	0.0000
Hotelling-Lawey Trace	0.0826	1.2800	0.2295	Hotelling-Lawey Trace	0.3082	4.7700	0.0000
Roy's Greatest Root	0.0826	1.2800	0.2295	Roy's Greatest Root	0.3082	4.7700	0.0000
Religion				**Breast Feeding**			
Wilks' Lambda	0.8152	1.6600	0.0230	Wilks' Lambda	0.8791	1.0300	0.4265
Pillai' Trace	0.1939	1.6700	0.0223	Pillai' Trace	0.1228	1.0200	0.4437
Hotelling-Lawey Trace	0.2154	1.6600	0.0238	Hotelling-Lawey Trace	0.1355	1.8200	0.0416
Roy's Greatest Root	01276	1.98	0.0238	Roy's Greatest Root	0.1173	1.8200	0.0416
Education				**Family Planning**			
Wilks' Lambda	0.5061	2.8900	0.0000	Wilks' Lambda	0.5649	1.8900	0.0001
Pillai' Trace	0.5741	2.6300	0.0000	Pillai' Trace	0.5273	1.8600	0.0001
Hotelling-Lawey Trace	0.8265	3.1700	0.0000	Hotelling-Lawey Trace	0.6210	1.9100	0.0000
Roy's Greatest Root	0.6201	9.7300	0.0000	Roy's Greatest Root	0.2715	4.2800	0.0000
Age				**Occupation**			
Wilks' Lambda	0.8756	1.0600	0.3843	Wilks' Lambda	0.6835	2.1000	0.0002
Pillai' Trace	0.1274	1.0600	0.3902	Pillai's Trace	0.3450	2.0300	0.0003
Hotelling-Lawey Trace	0.1386	1.0700	0.3787	Hotelling-Lawey Trace	0.4219	2.1600	0.0001
Roy's Greatest Root	0.1062	1.6500	0.0744	Roy's Greatest Root	0.2929	4.5700	0.0000
Parity group							
Wilks' Lambda	0.8483	1.3300	0.1341				
Pillai' Trace	0.1574	1.3300	0.1327				
Hotelling-Lawey Trace	0.1729	1.3200	0.1356				
Roy's Greatest Root	0.1106	1.7200	0.0592				

The test of parallelism, equality and flatness results for sex of baby are indicated in table 4.6

Table 4.6: Multivariate test of parallelism, equality and flatness by sex of baby

Source		Statistic	F-Value	Prob>F
Test of Parallelism				
Sex of baby	W	0.9545	0.8800	0.5653$\boldsymbol{e}$
	P	0.0455	0.8800	0.5653$\boldsymbol{a}$
	H	0.0477	0.8800	0.5653 $\boldsymbol{a}$
	R	0.0477	0.8800	0.5653 $\boldsymbol{u}$
Test of Equality(Level)				
Sex of baby	W	0.9999	0.2300	0.6323 $\boldsymbol{e}$
	P	0.0001	0.2300	0.6323 $\boldsymbol{a}$
	H	0.0001	0.2300	0.6323 $\boldsymbol{a}$
	R	0.0001	0.2300	0.6323 $\boldsymbol{u}$
Test of Flatness				
	W	0.0075	2442.1900	0.0000 $\boldsymbol{e}$
	P	0.9925	2442.1900	0.0000 $\boldsymbol{a}$
	H	132.0101	2442.1900	0.0000 $\boldsymbol{a}$
	R	132.0101	2442.1900	0.0000 $\boldsymbol{u}$

$\boldsymbol{e = exact, a = approximate, u = upper\ bound\ on\ F}$

Each of the four multivariate tests for parallelism and equality from table 4.6 gave a p-value of greater than 0.05. We therefore fail to reject the hypothesis of same profiles and conclude that the pattern of change in weights of babies did not differ by gender in both cases. Hence, the test of flatness was performed. The results of the test of flatness showed that all the four multivariate tests gave p-values less than 0.05.We therefore reject the hypothesis of same profiles and conclude that the pattern of change in mean weights of babies differed by gender overtime.

The results of the test of parallelism, equality and flatness for breast feeding are shown in table 4.7.

Table 4.7: Multivariate tests of parallelism, equality and flatness by Breast Feeding

Source	Statistic		F Value	Prob>F
Test of Parallelism				
Breast Feeding	W	0.9332	0.6500	0.9004
	P	0.0675	0.6500	0.9010
	H	0.0707	0.6500	0.8999
	R	0.0554	1.0300	0.4261
Test of Equality(Level)				
Breast feeding.	W	0.9847	1.8000	0.1671
	P	0.0153	1.8000	0.1671
	H	0.0153	1.8000	0.1671
	R	0.0155	1.8000	0.1671
Test of Flatness				
	W	0.0093	1971.7600	0.0000
	P	0.9907	1971.7600	0.0000
	H	107.0641	1971.7600	0.0000
	R	107.0641	1971.7600	0.0000

From table 4.7, all the four multivariate tests for parallelism and equality indicated a p2-value of greater than 0.05. We fail to reject the hypothesis of same profiles and conclude that the pattern of change in weights of babies did not differ by breast feeding for both parallelism and equality tests. Therefore, we carried out the test of flatness.

The flatness test results revealed that all the four multivariate tests; Wilks' Lambda, Pillai's Trace,Hotelling-Lawey Trace and Roy's Greatest Root had p-values less than 0.05.Hence, we reject the hypothesis of same profiles and conclude that the pattern of change in mean weights of babies differed by breast feeding over the period of observation.

Table 4.8 displays the results of the test of parallelism, equality and flatness for maternal age group.

Table 4.8: Multivariate tests of parallelism, equality and flatness by Maternal Age Group

Source	Statistic		F Value	Prob>F
Test of Parallelism				
Maternal age	W	0.9290	0.6900	0.8600
group	P	0.0720	0.6900	0.8580
	H	0.0760	0.6900	0.8610
	R	0.0510	0.9500	0.4980
Test of Equality(Level)				
Maternal age	W	0.9960	0.5000	0.6070
group	P	0.0040	0.5000	0.6070
	H	0.0040	0.5000	0.6070
	R	0.0040	0.5000	0.6070
Test of Flatness				
	W	0.0090	1945.9900	0.0000
	P	0.9910	1945.9900	0.0000
	H	105.6640	1945.9900	0.0000
	R	105.6640	1945.9900	0.0000

All the four multivariate tests for parallelism and equality had a p-value higher than 0.05. Hence, we fail to reject the hypothesis of same profiles and conclude that the pattern of change in weights of babies did not differ by maternal age group for both parallelism and equality tests. We therefore did the test of Flatness.

The results of the test of flatness proved that all the four multivariate tests showed p-values less than 0.05. Thus, we reject the hypothesis of same profiles and conclude that the pattern of change in mean weights of babies did not remain the same by maternal age group over time.

Table 4.9 shows the results of the test of parallelism, equality and flatness for parity group

Table 4.9 Multivariate tests of parallelism, equality and flatness by Parity Group

Source		Statistic	F Value	Prob>F
Test of Parallelism				
Parity group	W	0.8660	0 .9000	0.6350
	P	0.1390	0 .9000	0.6360
	H	0.1490	0.9000	0.6340
	R	0.0870	1.6000	0.0920
Test of Equality(Level)				
Parity group	W	0.9890	0.8500	0.4680
	P	0.0110	0.8500	0.4680
	H	0.0110	0.8500	0.4680
	R	0.0110	0.8500	0.4680
Test of Flatness				
	W	0.0130	1127.3500	0.0000
	P	0.9870	1127.3500	0.0000
	H	75.2870	1127.3500	0.0000
	R	75.2870	1127.3500	0.0000

From the table 4.9, the four multivariate tests for parallelism and equality in each case showed p-values higher than 0.05.Therefore, we fail to reject the hypothesis of same profiles and conclude that the pattern of change in weights of babies were the same by parity group in the two cases. Thus, the test of flatness was performed.

The results of the test of flatness proved that all the four multivariate tests had p-values less than 0.05. Therefore, we reject the hypothesis of same profiles and conclude that the pattern of change in mean weights of babies were not constant by parity group overtime.

4.3 Growth model

3-Parameter Gompertz and 3-Parameter Logistic models are the growth models used in this study. Their respective figures and tables are displayed below with $b1$, $b2$ and $b3$ representing α, β and γ respectively

4.3.1 Gompertz growth model

Figure 4.9 shows the pattern of mean change in weights of babies over time using 3-Parameter Gompertz growth model

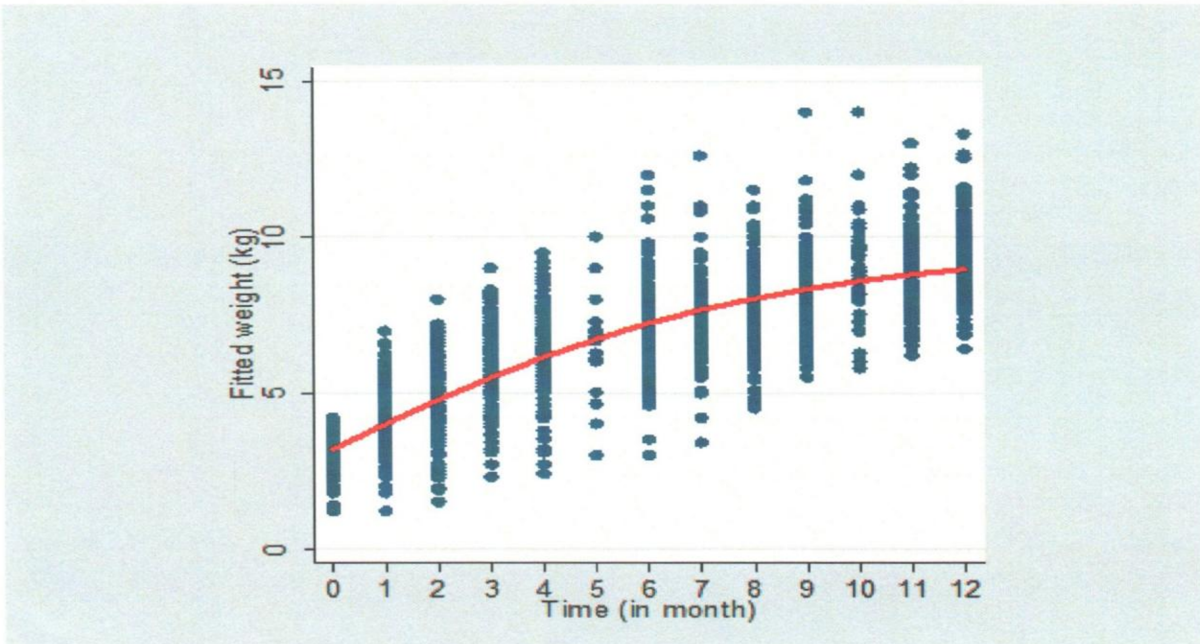


Figure 4.9 Gompertz growth pattern of mean baby weights overtime

Figure 4.9 shows that the general pattern of change in mean weights of babies increases over time. The Gompertz growth curve of the mean weights of babies over a one year period asymptotes occur at $y = 0$ and $y = k$ with the point of inflection showing at $y = \frac{k}{e}$ and $t = \frac{\alpha}{\beta}$ with a maximum growth rate of $\frac{\beta k}{e}$

Table 4.10 below shows the three parameter Gompertz growth model of baby weights over time.

Table 4.10: 3-Parameter Gompertz growth model of baby weights

3-parameter Gompertz function k*exp(-exp(α *(time-β)))					
Weight	Estimate	Standard Error	t	$P > t$	[95% confidence interval]
$\boldsymbol{k}$	9.6880	0.1140	84.3900	0.0000	9.4630
$\boldsymbol{\alpha}$	0.2210	0.0080	27.0200	0.0000	0.2050
$\boldsymbol{\beta}$	0.4620	0.0610	7.5100	0.0000	0.3410

Therefore, the fitted Gompertz growth model from equation 4.1 above is stated as shown below:

$$weight = 9.688\exp(-\exp(-0.221(x - 0.462))) \quad (3.49)$$

Where $x = 0,1,2,3, \ldots \ldots x_n$ (i.e. $x = time\ in\ months$)

The rate of change in mean weights of babies is then given as:

$$\frac{d(weight)}{d(x)} = 0.2210y\exp(0.1021 - 0.2210x) \quad (3.50)$$

Relative growth rate as a function of weight:

$$\frac{1}{y}\frac{d(weight)}{d(x)} = 0.2210(0.9862 - logy) \quad (3.51)$$

Relative growth rate as a function of time:

$$\frac{1}{y}\frac{d(weight)}{d(x)} = 0.2210e^{(0.1021-0.2210x)} \quad (3.52)$$

Maximum growth rate of mean weights of babies = $\frac{\mu k}{e} = \frac{0.102(9.688)}{2.72} = 0.3633 =$ 36.33%

Asymptotes occurred at $y = 0$ *and* $y = 9.688$ and the point of inflexion occurred at the point (0.46, 3.56)

4.3.2 Logistic growth model

Figure 4.10 shows the pattern of mean change in weights of babies over time using 3-Parameter Logistic growth model

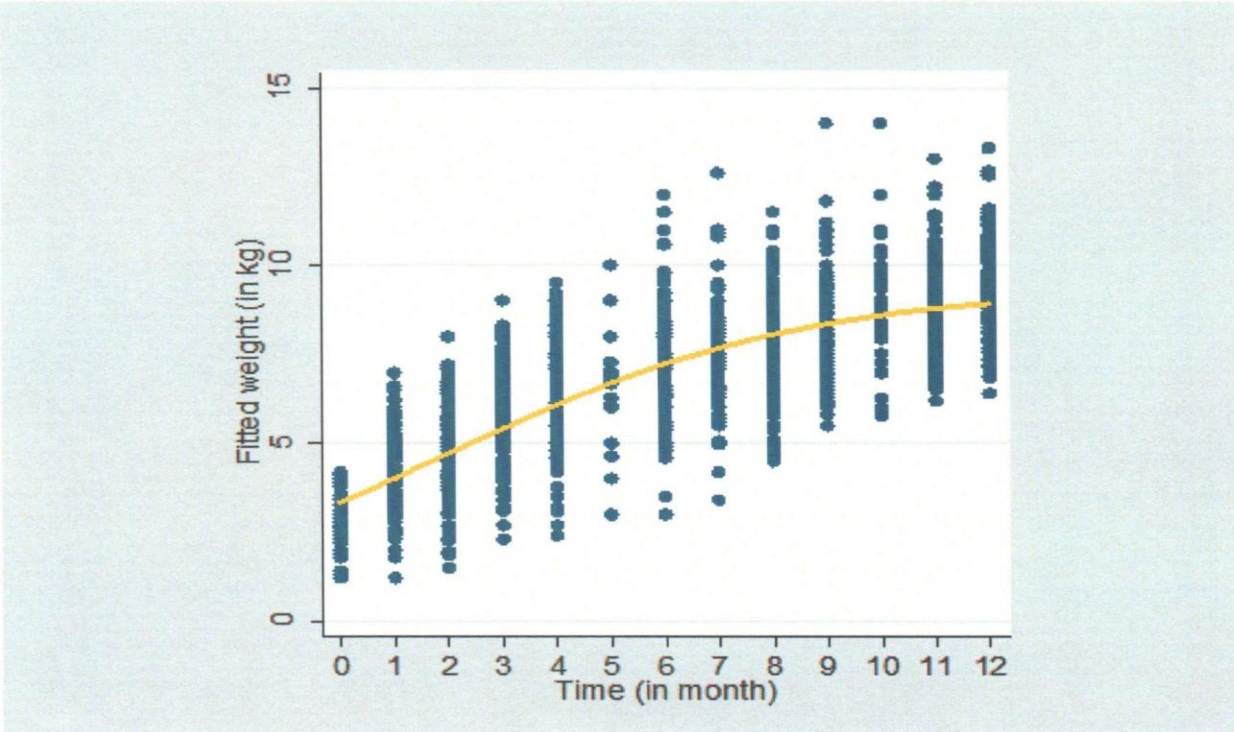


Figure 4.10: Logistic growth pattern of mean baby weights overtime

That of the logistic growth curve model has the asymptotes showing at

$y = 0$ and

$y = k$.

With the point of inflection at $y = \frac{k}{2}$ and $t = \frac{\alpha}{\beta}$

Table 4.11 shows the three parameter logistic growth model of baby weights over time.

Table 4.11: 3-Parameter Logistic growth model of weights of babies

3-parameter logistic function weight_=*k* /(1+exp(-*α* (t-*β*)))						
Weight	Estimate	Standard Error	t	$P > t$	[95%	confidence interval]
k	9.3410	2.0500	106.8700	0.0000	9.1700	9.5130
α	0.3020	0.0090	32.0090	0.0000	0.2840	0.3210
β	1.926	0.0770	24.0900	0.0000	1.7740	2.0780

The fitted 3-Parameter Logistic model is shown below:

$$weight = \frac{9.341}{(1+exp(-0.302(x-1.926)))} \qquad (3.53)$$

Where $x = 0,1,2,3, \ldots\ldots x_n$ (i.e. $x = time\ in\ months$)

The rate of change in mean weights of babies is then given as;

$$\frac{d(weight)}{d(x)} = 0.0323y(9.3410 - y) = 0.3017y - 0.0323y^2 \qquad (3.54)$$

Relative growth rate as function of weight:

$$\frac{1}{y}\frac{d(weight)}{d(x)} = 0.0323(9.341 - y) \qquad (3.55)$$

Relative growth rate as function of time:

$$\frac{1}{y}\frac{d(weight)}{d(x)} = \frac{0.3020}{1+e^{0.3020x-9.341}} \qquad (3.56)$$

Maximum growth rate $= \frac{\mu k}{4} = \frac{0.5816(9.341)}{4} = 1.358 = 135.8\%$

Asymptotes occurred at $y = 0$ *and* $y = 9.341$ and the point of inflexion occurred at the point (0.46, 4.67)

Where $\mu = \alpha\beta$

Hence the point of inflection for this growth model is (0.157, 4.671)

Thus at 5% significant level, the logistic growth model indicated that there was a significant increase in weight with time but showing inflection at (0.157, 4.671). The optimum increase in the weight of the babies from the logistic growth pattern was 4.59.

4.3.3 Growth Model comparison

Gompertz and Logistic models are compared using the model selection criteria as shown below.

Table 4.12: Model selection criteria for Gompertz and Logistic models

Model	R-squared	Adjusted R-squared	RMSE	Residual deviance
Gompertz	0.9740	0.9740	1.1350	9442.0630
Logistic	0.9730	0.9730	1.1460	9503.5630

Table 4.12 gives the model selection criteria of Gompertz and logistic models. The Gompertz model had lower root mean square error of 1.135, residual deviance of 9442.063 and equal higher values of R-squared and Adjusted R-squared of 97.4% compared to the Logistic model with higher values of root mean square error of 1.146 and residual error of 9503.563 and equal lower values of R-squared and Adjusted R-squared of 97.3%. Since the Gompertz model gives the least values of root mean

square error and residual deviance, it is selected as the better model for prediction of the mean change of weights of babies over time as compared to the logistic model.

4.3.4 Statistics for Covariance Structure Models

Comparison analysis of Akaike's Information Criterion (AIC) and Bayesian Information Criterion (BIC) of the various covariance models is indicated on table 4.12 below.

Table 4.13: Statistics for covariance Structure Models

Structure	AIC	BIC
AR(1)	10540.7000	10541.8000
Compound Symmetry	9267.8000	9268.9000
Variance Component	13411.3000	13411.8000
ARMA(1,1)	**9251.9000****	**9253.6000****

** means smallest

The table shows that the autoregressive moving average model contains the least values for both AIC (9251.9000) and BIC (9253.6000).

Following the information criterion, the first order autoregressive moving average variance-covariance model was selected for modeling. It implies that there exists a strong correlation between weights of babies at times t *and* $t+1$.

4.3.5 Parameter Estimates of Mixed Effects Model

Table 4.14 gives the output of the parameter estimates of the variables in this study

Table 4.14: Summary of parameter estimates of linear mixed model

Effect	Estimate	SE	*t value*	P>|*t*|	[95% CI]	
	Gender relative to female					
Male	0.0195	0.0412	0.4700	0.635	-0.0613	0.1003
	Religion relative to Islam					
Christianity	-0.0557	0.0823	-0.9500	0.3420	-0.1707	0.0592
Traditional	-0.3386	0.0823	-4.1200	0.0000	-0.4999	-0.1770
	Level of education relative to primary					
Junior High School	-0.0238	0.0755	-0.3200	0.7530	-0.1719	0.1243
Senior High School	0.0809	0.0728	1.1100	0.2670	-0.6184	0.2236
None	0.0398	0.0755	0.5300	0.5980	-0.1082	0.1877
Tertiary	0.6184	0.0894	6.9200	0.0000	0.4432	0.7936
	Marital status relative to not married					
Married	0.0126	0.0591	0.2100	0.8320	-0.1033	0.1283
Breastfeeding type relative to Exclusive						
Mixed	-0.3120	0.0530	-5.8900	0.0000	-0.4159	-0.2081
Nonexclusive	-0.4635	0.0636	-7.2900	0.0000	-0.5882	-0.3388
	Family planning relative to pills					
Condom	0.1558	0.0818	1.9000	0.0570	-0.0047	0.3163
Injection	0.1755	0.0830	2.1100	0.0350	0.0127	0.3381
Natural	0.5288	0.0897	5.9000	0.0000	0.3529	0.7046
Neoplant	-0.1642	0.1322	-1.2400	0.2140	-0.4233	0.0950
Never	0.0442	0.0953	0.4600	0.6430	-0.1426	0.2309
	Mother's age group relative to one year					
25-32	-0.0993	0.0513	-1.9400	0.0530	-0.1998	0.0013
33+	0.0946	0.0773	1.2200	0.2210	-0.0569	0.2460
	Occupation of mother relative to unemployed					
Student	0.2323	0.0990	2.3500	0.0190	0.0382	0.4263
Government employee	0.0974	0.0893	1.0900	0.2750	-0.0776	0.2720
Self employed	-0.1867	0.0911	-2.0500	0.0410	-0.3654	-0.0080
	Parity group relative to first time of birth					
2-3	0.3632	0.0930	3.9000	0.0000	0.1808	0.5456
4-5	0.4121	0.0849	4.8500	0.0000	6.0634	6.6990

Table 4.14 indicates that factors such as mothers who attained tertiary level of education, those who stopped injection family planning method before conception, mothers who practiced natural family planning method prior to the pregnancy, those who were students, parents who delivered two to three times as well as mothers who

gave birth four to five times are significant determinants of heavier weights of babies in the municipality.

There also existed differentials among weights of babies whose mothers were affiliated to the traditional religion, mothers who breast fed their babies on only breast milk and water, parents who did not exclusively breast feed their babies as well as those who were self-employed even though the factors did not have a significant influence on the mean change in weights of babies overtime.

Male babies are expected to have significantly higher weights relative to their female counterpart overtime.

Apart from babies whose mothers obtained Junior High School level of education, babies whose mothers attained Senior High School and tertiary levels of education as well as the mothers who did not have any formal level of education are expected to significantly weigh heavier relative to babies whose maternal level of education is Primary school overtime.

The weights of babies of married mothers are anticipated to significantly increase overtime compared to those of the unmarried parents.

Aside weights of babies whose parents used neo-plan family planning method, it is anticipated that weights of babies whose mothers ever used condoms, injection, natural family planning methods as well as mothers who never used any family planning method will significantly become heavier compared to those of mothers who used pills.

With the exception of babies born by self-employed mothers, those delivered by student mothers as well as mothers employed by government are expected to weigh heavier compared to those of the unemployed mothers. Also, weights of babies whose mothers delivered two to three times as well as those of babies whose parents gave birth to four to five times are expected to be heavier than weights of babies whose mothers delivered once.

4.3.5.1 Full Model

The full model for the linear mixed effects model is given below;

$$weight = 0.0195x_1 - 0.0557x_2 - 0.3386x_3 - 0.0238x_4 + 0.0809x_5 + 0.0398x_6 + 0.6184x_7 + 0.0126x_8 - 0.3120x_9 - 0.4635x_{10} + 0.1558x_{11} + 0.1755x_{12} + 0.5288x_{13} - 0.1630x_{14} + 0.0442x_{15} - 0.0993x_{16} - 0.0946x_{17} + 0.2323x_{18} + 0.0974x_{19} - 0.1867x_{20} + 0.3632x_{21} + 0.4121x_{22} \quad (3.54)$$

Where,

x_1 = Male baby, x_2 = Christianity, x_3 = Traditional religion, $\boldsymbol{x_4}$= Junior High School x_5= Senior High School, x_6= No formal education(none), x_7= Tertiary , x_8= Married,x_9= Mixed (breast milk and water only), x_{10}= Mothers who did not practice exclusive breast feeding (Nonexclusive), x_{11}= Condom x_{12}= Injection, x_{13} = Mothers who used natural family planning method,x_{14} = mothers who have never used contraceptives, x_{15}=Exclusive breast fed babies,x_{16}= Mothers whose ages are between 25-32years,x_{17}= Mothers who were 33Years and above, x_{18}=mothers who were students , x_{19} = mothers who were employed by government , x_{20}= Mothers who were self-employed , x_{21}=mothers who gave birth 2-3 times ,x_{22}=mothers who gave birth 4-5times.

4.3.5.2 Reduced model for prediction

Stepwise selection criterion was used to fit the reduced model and new parameter esti mates are shown in table 4.15.

Table 4.15: Model Selection for Prediction

Step	Label	Partial R-squared	Model R-squared	Mallows' C(p)	F-value	Pr > F
1	Nonexclusive breast feeding	0.8127	0.8127	1680.1100	13250.1000	0.0001
2	Self-employed	0.0468	0.8595	498.4640	1018.0900	0.0001
3	Traditional religion	0.0027	0.8745	127.1940	89.9700	0.0001
4	Tertiary education	0.0027	0.8772	60.4450	67.5400	0.0001
5	Injection Family planning	0.0017	0.8788	20.2944	41.9700	0.0001

The variables; marital status, occupation, religion, education and family planning in table 4.14 above were selected by stepwise criterion to fit the model. Sex of baby, age of mother, parity group and breast feeding were not significant in the model and hence were left out. Estimates of the reduced model are indicated in table 4.15.

Table 4.16: Parameter estimates of reduced model

Variable	Estimate	Standard Error	Type II SS	F Value	Pr > F
Nonexclusive	1.1259	0.0828	1124.3225	184.5800	0.0001
Self-employed	0.5412	0.0643	431.9167	70.9100	0.0001
Traditional religion	0.3185	0.0375	439.5908	72.1700	0.0001
Tertiary education	0.3724	0.0564	265.6510	43.6100	0.0001
Injection Family planning	- 0.1707	0.0860	23.9720	3.9400	0.0474

Reduced model equation

$$\hat{Y} = 1.1259w_1 + 0.5412w_2 + 0.3185w_3 + 0.3724w_4 - 0.1707w_5 \qquad (3.55)$$

Where:

w_1 = Mothers who practiced Nonexclusive breast feeding type

w_2 = Mothers who were self-employed

w_3 = Mothers affiliated to traditional religion

w_4 = Mothers who attained tertiary level of education

w_5 = Mothers who practiced Injection Family planning Method

4.4 Diagnostics

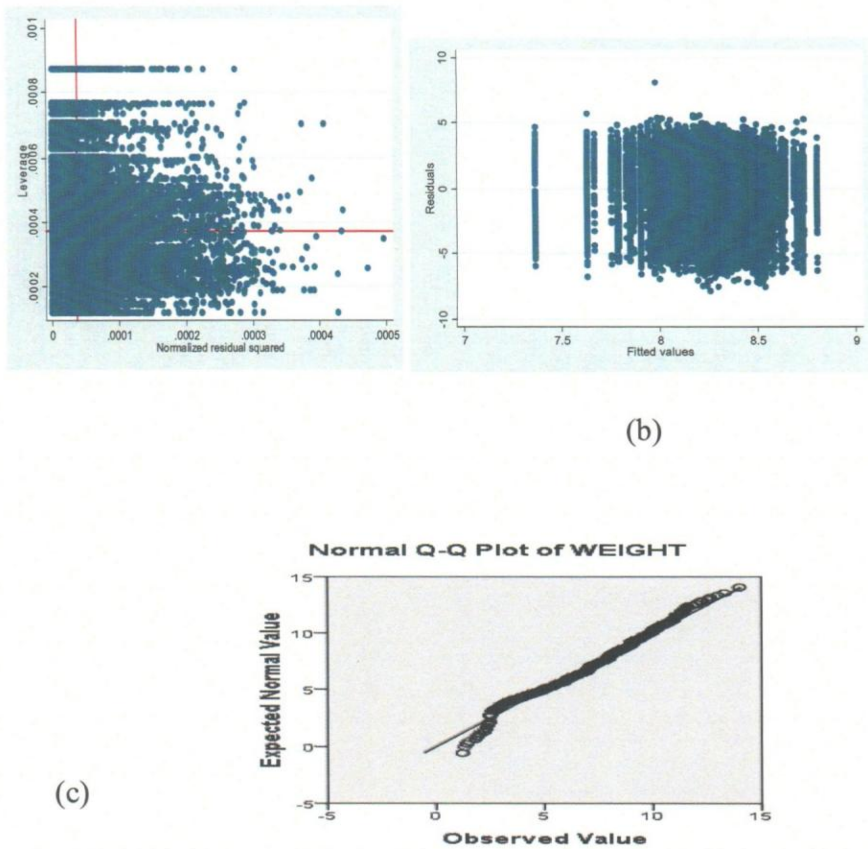
Figure 4.11 below gives the diagnostic analysis of residual plots of the weights of babies.

Figure 4.11a indicates the leverage plots with Cook's distance less than one which suggests that there is no influence of outliers in the reduced model.

Figure 4.11b indicates the residual versus fitted plot which suggests the assumption of random distribution is met.

Figure 4.11c shows that the assumption of normality is achieve

Residual Plots of Weights of babies



(a) (b)

(c)

Figure 4.11: Residual Plots of weights of babies

4.5 Discussion

Records of three hundred weights of babies for this research work were taken from January 2013 to December 2013.Sixty five of these records were left out due to the inability of the nursing mothers to attend at most six post natal care within the year. The available records of weights of babies qualified for the analysis were two hundred and thirty five (235) observations collected from the seven health facilities in the municipality.

Out of the two hundred and thirty five participants, 130 were males whilst 105 represented females. The mean birth weights of males and females are 2.71kg and 2.74kg respectively.

The correlation and variance-covariance structure of the weights of babies over time statistically did not prove to be compound symmetric but rather first order autoregressive moving average

The profile plot by average change in weights of babies by breastfeeding type remain the same from month zero to month one which is obvious since a one month old child does not drink water or take any liquid foods apart from only breast milk.

Among the three classes of breastfeeding types, infants who were not exclusively breastfed for the first six months of birth realized the best mean weights of babies compared to babies who solely depended on breast milk and infants who took breast milk and water only (mixed).

Sokol et al. (2007) reported that poor feeding practices including sub-optimal breastfeeding is still widespread and also results in malnutrition which mostly cause more than half of all child deaths.

The pattern indicated by the profile of mean change in weight by mothers' educational level explained that mothers who attained tertiary level of education delivered babies with better mean birth weights and subsequent weights than mothers who had no education and those who completed primary school.

This supports the findings of Joyce (1994) who concluded that maternal highest level of education belongs in both the demand function and the birth weight production function, thus a greater influence in giving birth to overweight or normal babies compared to maternal parents whose educational level is very low or nil but contradicted Rosenzweig,M.R and Schultz,T.P. (1983) who were of the view that parental education affected the choice of health inputs but has no direct effect on birth weight.

The profile plot for religion also proved an interesting pattern of an approximately constant increasing growth of average change in weights of babies for Christian and Muslim mothers whilst those of babies born by mothers who belong to the traditional religion showed fluctuating pattern. It gives the indication that children born of Christian and Muslim mothers have heavier weights than those born of mothers who are traditional believers.

Dhall and Bagga (1995) revealed a significant effect of religion on birth weight among babies born in North Indian, as well as the effect of maternal age on birth weight.

Type of contraceptive use prior pregnancy showed injectable to have better growth pattern than that of the other family planning types as demonstrated in profile plots with baby weights. This was confirmed in the mixed model as injectable was important in the model.

Another fascinating profile plot is the one of baby weight by mothers' age group. There were very close similarities exhibited by mean change in weights of the babies by all the age groups of the mothers' right from the month at birth to the fifth month and also from months seven and ten with months six, eight, nine, eleven and twelve.

The pattern of profile of baby weight by mother's occupation brought to light equivalent average change of the babies for mothers who were unemployed, self-employed, students, and government of Ghana workers. Occupation in the analysis was not significant confirming Conley & Bennett (2000); who found out that no occupational income or education has effects on the probability of low birth weight among infants.

Another maternal factor profile plot is the graphical display of the pattern of baby weight by mother's parity group. This profile showed that mothers who gave birth up to two-three times had the best mean change in weights of babies compared to those who gave birth once as well as those who had four –five number of births which was the least.

In identifying the pattern of change in weight of baby by group, it was realized that the mean change in weights of babies for males and females were similar and increased over time. The test of parallelism, equality and flatness revealed the same and identical pattern for both sexes with the mean change in weight of baby varying over time.

Therefore, the sex of baby had no significant influence on the weight of the baby but time had meanwhile, time and group did not interact. The time effect on the weight of the baby was expected since growth of weights of babies is time dependent.

The test of parallelism and equality (test of levels) strongly proved that maternal factors such as educational status, age, last type of family planning employed as well as biological factors of both nursing mother and the baby such as breastfeeding and sex of baby were statistically not significant but flatness was at 5% significance level.

Meanwhile, maternal factors such as: religious denominations, occupation, parity, injection as last type of family planning practiced by nursing mother were significant.

Thus, the mean weight of a baby in the municipality can significantly be predicted by maternal factors such as occupation, parity group, injectable family planning method, breastfeeding type, level of education, religion, health facility.

Parallelism test gave the confirmation that there existed differences in the pattern for the various educational levels indicated in the profile plot. The distinct rate and pattern of increment portrayed for mean weights of babies whose mothers attained tertiary level of education is in favor of Sachedeva et al., (2013) who found out that a rising level of education is a protective factor against low birth weight as well as Silvestrin et al., (2013) whose findings concluded that the lower the educational level of the mother, the greater the vulnerability of delivering a baby with a low birth weight. Therefore, nursing mothers with tertiary qualification have the weights of their babies higher compared to the nursing mothers without higher educational level or none at all.

Also, there were no differences in the weights of babies by mother's age groupings. It suggested that babies born of mothers in the age category of 17-24 years weighed more than mothers whose ages range from 25-32 years and 33 plus years ranging from months three to seven whilst mothers age 33 and above years led in terms of baby weights from months zero to six and months eight to eleven .This research piece is contrary to Gibbs et al., (2012) who showed that young age is associated with a short cervix and a small uterine volume which is associated with preterm birth and consequently low birth weight.

Both Gompertz and Logistic growth models proved a significant increase pattern in the growth of babies and estimating the maximum growth rate at 1.517 and 4.59 kg respectively for a month with high reliability and variability in monitoring the growth rate of babies. The general growth pattern of the baby weight disclosed that while Gompertz model showed an increasing exponential growth pattern and is asymmetrical about inflection, Logistic growth pattern showed a function which is increasing in a quadratic growth pattern of mean weights of babies in the Bolgatanga Municipality overtime with high level of significance of all the parameters in the model at 5% significant level and is symmetrical about the inflection. Prediction of baby weight with time as measure of growth is to be done with high accuracy and precision. Even-though the two growth models have approximately the same high degree of variability indicating high reliability it their prediction of baby weights, Gompertz model proved to be relatively better because it gave the least values of root mean square error and residual deviance. Hence Gompertz model was selected as the better model for prediction of the mean change of weights of babies over time in the municipality with the growth equation

$weight = 9.688\exp(-\exp(0.221 - 0.462t))$ and increasing at a growth rate of $\frac{d(weight)}{d(t)}$ = 0.462y exp (0.221 - 0.462t) with the maximum achievable weight increment per month as 1.517kg.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The analysis revealed that the profile of mean weights of male and female babies did not show any gender difference in the mean weights. Though there existed some mean change in weights of males and females from the month of birth to a one year period, the pattern and level of the change in their mean weights were the same for gender.

The mean weights of babies of the profiles of mother's age group did not indicate any maternal age group differences.

The tests of parallelism and equality results for sex of baby, breast feeding, mother's age group and parity group from all the four multivariate tests; Wilks' Lambda, Pillai's Trace,Hotelling-Lawey Trace and Roy's Greatest Root showed p-values greater than 0.05.

We fail to reject the hypothesis of same profiles and conclude that the pattern of change in weights of babies did not differ by these groups.

The test of flatness however differed by the groups since the p-values of all the four multivariate tests were less than 0.05.Hence, we reject the hypothesis of same profiles and conclude that the pattern of change in mean weights of babies did not differ by these groups.

The nonlinear growth pattern overtime was further confirmed and the trend analysis developed in Gompertz and logistic growth models. The 3-parameter Gompertz and logistic growth models were statistically significant at the 5% significance level. From the model selection criteria, Gompertz model with the lower values of root mean square error and residual deviance compared to the logistic model, was selected as better growth model as the growth pattern and for reliable prediction of weights of babies in the municipality at 97.4% variability.

Comparison analysis of Akaike's Information Criterion and Bayesian Information Criterion of the various covariance models showed that first order autoregressive moving average had the least AIC and BIC values of (9251.9000) and (9253.6000) respectively. Hence, ARMA (1, 1) variance-covariance model was selected for modeling.

The mixed model showed that mothers who attained tertiary level of education, those who stopped using injectable family planning methods prior to pregnancy, mothers who used natural family planning method, student mothers, parity group of two to three times of births as well as parity group of four to five number of births were significant determinants of weights of babies in the municipality.

Finally, all the weights of babies that we considered in our study established that growth of weights of babies studied is not linear but indicated non-linear growth pattern of Gompertz and/or logistic over time. Similarly, all the profiles of both the maternal and biological factors showed a nonlinear growth pattern over time.

From the study conducted, Gompertz model and the reduced mixed model are more suitable for explaining the mean weights of babies in the municipality overtime.

The Gompertz model equation is given as:

$$weight = 9.688\exp(-\exp(-0.221(x-0.462)))$$

Whilst the reduced model equation is given as:

$\hat{Y} = 1.1259w_1 + 0.5412w_2 + 0.3185w_3 + 0.3724w_4 - 0.1707w_5$

The biological factors of the baby as well as maternal factors such as the sex of baby, maternal religious affiliation, type of breast feeding, maternal age group and parity are important determinants of weights of babies over time.

5.2 Recommendations

From the results of the research work we recommend the following:

i. Healthcare providers should continuously promote regular antenatal and postnatal healthcare attendance of mothers to facilities in the municipality this is because out of a target population of 300 weights of babies collected over a one year period, 65 of them were weighed for at most five months within the one year period.

ii. There is the need for quality education for everyone in the country particularly girls since this study indicated that mothers who attained high level of education had their babies weighing heavier than mothers with low level of education.

iii. Further studies are required to investigate why mothers who used injectable family method prior to pregnancy had their babies recording heavier weight compared to mothers who used the other contraceptives prior to pregnancy

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